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JOURNAL

OF

THE ROYAL SOCIETY

OF

WESTERN AUSTRALIA, INC.

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Vol. XXXI
1944 - 1945

The Authors of Papers are alone responsible for the statements and the opinions expressed therein.

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1948.

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CONTENTS.

VOLUME XXXI.

The Royal Society of Western Australia (Inc.).

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR ENDING 30th JUNE, 1945.

Ladies and Gentlemen,

Your Council begs to submit the following report for the year ending 30th June, 1945.

Council.—At its first meeting the Council appointed an Executive Committee of seven to deal with the routine business of the Society, and to submit quarterly reports to the full Council.

Four ordinary, and one special, meetings of Council, and six meetings of the Executive have been held.

During the year Miss A. Baird and Mr. A. C. Shedley were appointed by Council to fill the vacancies caused by the resignations of Dr. Carroll and Dr. Miles. Mr. J. M. Thomson accepted office as Joint Honorary Secretary in place of Dr. Miles, but later tendered his resignation on his appointment to a post in New South Wales. Dr. Watson agreed to act as Joint Honorary Secretary for the remainder of the Session.

Finance.—There is a credit balance of £262 17s. 6d. in the General Fund; the Endowment Fund amounts to £314 7s. 4d.; and the Medal Fund to £9 12s. 7d.

The increase in the cost of publication, noted in the last Annual Report, has been maintained and the Society will have difficulty in meeting its obligations to the Government Printer.

This difficulty has been partially offset by a Special Grant of £100, for the current year, made by the Government on the representations of Council. The thanks of the Society are due to the Premier for this generosity.

Membership.—There has been a further increase in the total membership of the Society, which now numbers 181, composed of:—

Honorary members	7
Corresponding members	9
Life members	2
Ordinary members	115
Associate members	28
Student members	20

The names of three Ordinary Members were added to the Register during the year; one Associate was transferred to full Membership, and one Associate member resigned.

Journal.—The first part of Volume XXIX has been published, and distributed to those members who signified their desire to receive it in parts as published. Progress has been made with the second part of this number, and with Volume XXX. It is hoped that the appearance of these will not be long delayed.

A report has been prepared on the date of publication of back numbers of the Journal, and will be published in part two of Volume XXIX.

Library.—An exchange agreement has been entered into with the Otago University Library. A number of exchanges with overseas institutions, which had been suspended owing to wartime risks in transport, have now been resumed.

The arrangement of the books and periodicals in the Library has been reorganised in conformity with the Dewey system, usually employed in libraries. A number of periodicals also received by other libraries in Perth, have been removed from our shelves owing to shortage of accommodation. Where possible these have been offered to other libraries to extend their holdings, and the remainder have been placed in storage with a view to their being made available to overseas libraries which may have been destroyed as a result of the war. Current numbers of these periodicals will remain on our shelves.

A request from the editor of Pitt's Catalogue of Scientific and Technical Periodicals in Australian Libraries for this Society's co-operation in the preparation of a new edition of the catalogue has been complied with, and the work completed as far as this library is concerned.

Reciprocal Arrangement with Royal Societies of Australia.—For the benefit of members of the Society who may be visiting other States, Council has entered into agreements with the Royal Societies of the other States in Australia whereby members of this Society are entitled to the privileges of attending meetings, and to the use of the libraries, of such Societies.

Kelvin Medal.—The 1945 award of the Society's Kelvin Medal, for distinguished work in Science connected with Western Australia, has been made to Mr. L. Glauert.

Donations Received.—The Society has received from the Royal Society of Tasmania a replica of the Medal struck on the occasion of the centenary of that Society in 1944.

A gift of fossils has been received from Professor Carl C. Branson, of the University of Kentucky.

R. T. PRIDER,
President.

A. G. NICHOLLS,
E. M. WATSON,
Joint Hon. Secretaries.

ABSTRACT OF PROCEEDINGS, 1944–45.

11th July, 1944—

Annual Meeting in Gledden Hall. Presidential Address: "The Chemistry and Chemical Exploitation of Western Australian Plants," by Dr. E. M. Watson

8th August, 1944—

Paper.—"Mineralogy of Some Soils from the Margaret River District," by Dr. D. Carroll.

Address.—"Overland to the Ord River," by Mr. C. F. H. Jenkins.

12th September, 1944—

Paper.—"Some Western Australian Lamprophyres," by Dr. K. R. Miles.

Addresses.—(1) "Tin," by Mr. R. A. Hobson.
(2) "Anti-bacterial Substances Produced by Moulds," by Dr. D. E. White.

Election of Members.—Messrs. E. J. Ramm and R. P. Roberts as ordinary Members.

10th October, 1944—

Paper.—"Some Chaetognatha from Western Australia," by Mr. J. M. Thomson.

Addresses.—(1) "Tungsten and Molybdenum," by Dr. K. R. Kiles.
(2) "Botany of the East Kimberleys," by Mr. C. A. Gardner.

14th November, 1944—

Papers.—(1) "Some Chaetognatha from Western Australia," by Mr. J. M. Thomson.
(2) "An Ecological Study near Beraking Forest Station," by Mr. R. F. Williams, communicated by Miss A. M. Baird.

Addresses.—(1) "Tantalum," by Mr. H. P. Rowledge.
(2) "Snakes," by Mr. L. Glauert.

Election of Member.—Mr. H. R. Harper as an Ordinary Member.

12th December, 1944—

Exhibits.—
(1) "A New Genus of Orchid as yet Undescribed," by Mr. C. A. Gardner.
(2) "Some Western Australian Owls," by Mr. L. Glauert.
(3) "The Electronic Charge," by Mr. J. Shearer.
(4) "Local Examples of Biological Control," by Mr. C. F. H. Jenkins.
(5) "The Spekker Absorptiometer," by Mr. A. G. Turton.

13th March, 1945—

Address.—"Some Aspects of Soil Erosion," by Dr. L. J. H. Teakle.

Films.—(By courtesy of the Shell Oil Co., of Aust., Ltd.)
(1) "Heritage."
(2) "World of Plenty."

10th April, 1945—

Paper.—"The Essential Oils of *Eucalyptus kochii* and *E. campaspe*," by Dr. E. M. Watson.

Address.—(1) "*E. kochii* and *E. campaspe*," by C. A. Gardner.
(2) "Genetics in Relation to Stock Breeding," by Mr. C. B. Palmer.

8th May, 1945—

Paper.—"Notes on the Distribution of the Rabbit Flea (*Echidnophaga myrmecobii*)," by Mr. C. F. H. Jenkins.

Address.—"Coral Reefs of Queensland and Western Australia," by Dr. C. Teichert.

12th June, 1945—

Paper.—"The Cretaceous Stratigraphy of the Lower Murchison," by Prof. E. de C. Clarke and Dr. C. Teichert.

Address.—"Laterite with Special Reference to its Occurrence in Western Australian Soils," by Mr. G. H. Burvill.

THE ROYAL SOCIETY OF WESTERN AUSTRALIA, INCORPORATED.

Statement of Receipts and Expenditure for the Year ended 30th June, 1945.

Receipts.	£	s.	d.	£	s.	d.
General Fund—						
Balance at 30th June, 1944				174	16	11
Interest—						
Current Account to 31st May, 1945	2	12	8			
War Loan, 1959	1	6	0			
				3	18	8
Annual Subscriptions—*						
Current and Arrears	113	19	0			
Paid in Advance	5	13	4			
				119	12	4
Government Grant				200	0	0
Authors' Reprints and half cost of Blocks				89	18	0
Sales—						
Copies of this Society's Journal	6	2	3			
Mueller Botanical Society's Journal		13	0			
				6	15	3
Exchange and duty on cheques					4	6
				£595	5	8

Expenditure.	£	s.	d.	£	s.	d.
Petty Expenses, including Postage, Exchange				9	12	4
Clerical Assistance				10	13	5
Rent—Institution of Engineers				30	0	0
Meetings—Catering, etc.				18	8	6
Library—Bookbinding				3	4	0
Government Printer—						
Volume XXVIII., Papers 8, 9, 11, 12, 13 and Presidential Address: (£ s. d.)						
Printing 207 2 2						
Blocks 23 0 9						
	230	2	11†			
Balance Sheet, 1943-44	2	3	5			
				232	6	4
Stationery—						
Government Printer Subscriptions forms, etc.	1	17	3			
E. S. Wigg and Sons—Cash Book	4	19	6			
				6	16	9
Subscription—						
International Commission on Zoological Nomenclature	4	4	11			
Royal Society of Canada—Author Index, 1907-1941		11	7			
				4	16	6
Medal Award	15	15	0			
Expenses in Striking Medal		15	4			
				16	10	4
Balance at 30th June, 1945—						
Cash at Bank	281	8	7			
Less Cheques not presented	18	19	9			
Balance at Bank	262	8	10			
Cash in hand		8	8			
				262	17	6
				£595	5	8

Endowment Fund—	£	s.	d.	£	s.	d.
Balance at 30th June, 1944:						
250 War Savings Certificates at valuation	225	0	0			
War Loan, 1956	40	0	0			
War Loan, 1959	40	0	0			
Cash at Bank	1	15	7			
				306	15	7
Interest—						
Estimated on War Savings Certificates	6	5	0			
War Loan, 1956	1	6	0			
Bank Account			9			
				7	11	9
				£314	7	4

	£	s.	d.	£	s.	d.
Balance at 30th June, 1945—						
250 War Savings Certificates at valuation	231	5	0			
War Loan, 1956	40	0	0			
War Loan, 1959	40	0	0			
Cash at Bank	3	2	4			
				314	7	4
				£314	7	4

Medal Fund—	£	s.	d.		£	s.	d.
Balance at 30th June, 1944	9	9	0	Balance at 30th June, 1945—			
Interest on Bank Account		3	7	Cash at Bank	9	12	7
	£9	12	7		£9	12	7

*Includes balances arising from half-cost of blocks, etc. †Includes 15s. 4d. Sales Tax, incidence of which is queried by auditors.

Balance Sheet as at 30th June, 1945.

Liabilities.	£ s. d.	£ s. d.	Assets.	£ s. d.	£ s. d.
Subscriptions in Advance		5 13 4	Furniture and Equipment—		
Government Printer, Vol. XXIX.—			Library shelving at cost stated in Balance Sheet, 30th June, 1944†		90 19 11
Printing (Papers 1-9 only)	220 6 8		Investments—		
Sales Tax*	31 16 7		War Loan, 1959	40 0 0	
		252 3 3	War Loan, 1956	40 0 0	
Sundry Creditors		1 13 8	War Savings Certificates at valuation	231 5 0	
Surplus Assets over Liabilities		437 6 3			311 5 0
			Balance at Bank—		
			General Fund	262 8 10	
			Medal Fund	9 12 7	
			Endowment Fund	3 2 4	
					275 3 9
			Cash in hand		8 8
			Subscriptions in Arrears		10 10 0
			Sundry Debtors		8 9 2
		£696 16 6			£696 16 6

*Incidence of this Taxation disputed. †No depreciation has been allowed since the original purchase 25th February, 1941, nor has any valuation been made of the books on these shelves.

Audited and found in agreement with books, receipts and vouchers produced. We consider this to be a true statement of the Royal Society's Accounts within the limits of the forms and practices of the Society.

F. G. FORMAN, Hon. Treasurer.
10th July, 1945.

S. E. TERRILL.
C. E. S. DAVIS.
Hon. Auditors.
10th July, 1945.

THE ROYAL SOCIETY OF WESTERN AUSTRALIA INC.

KELVIN MEDALLIST, 1945.

The Royal Society's Kelvin Medal was instituted in 1924 to be awarded at four-yearly intervals for distinguished work in Science in Western Australia. The recipient chosen for 1945 was Mr. Ludwig Glauert, Curator of the Western Australian Museum.

Ludwig Glauert was born in Sheffield, England, and received his education at the Sheffield Royal Grammar School, Firth College and University College (Technical Department). He was for many years a member of the Sheffield Naturalists and an associate of the Yorkshire Naturalists' Union, serving on the Yorkshire Glacial Committee and the Carboniferous Rocks Fossil Flora and Fauna Committee. He was elected a Fellow of the Geological Society in 1900.

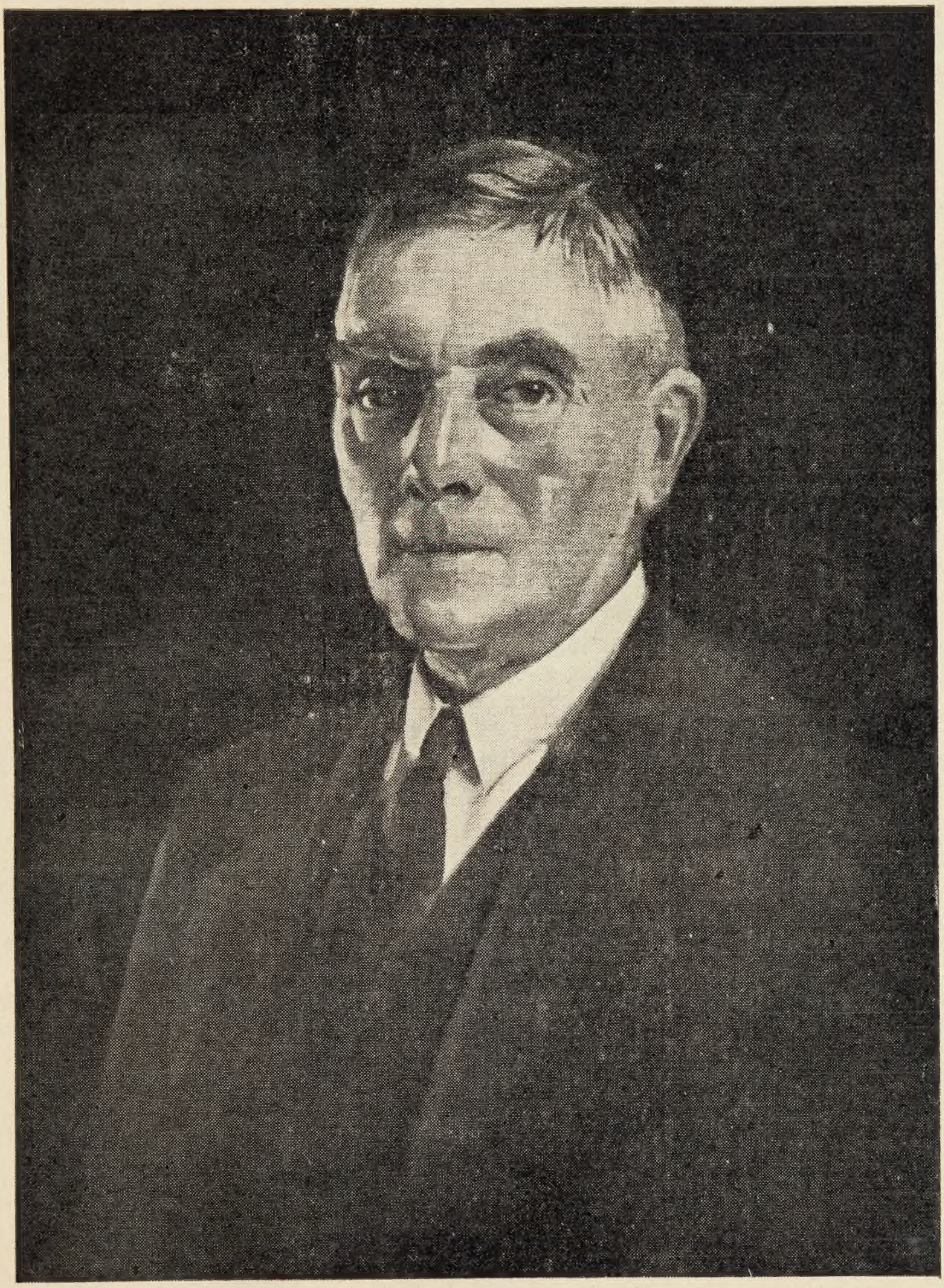
In 1908 he came to Western Australia where he received a temporary appointment on the staff of the Geological Survey. The next year he commenced his long association with the Western Australian Museum when he was sent to the Mammoth Cave, Margaret River, to undertake excavations in search of fossil marsupial remains. This work continued at intervals during the summer season until 1915 with fruitful results.

He enlisted for active service in 1917 and after the armistice was transferred to the Education Service in France, being later moved to England as a lecturer in A.I.F. Depots in the United Kingdom. On demobilisation he rejoined the staff of the Museum and later graduated in Arts at the University of Western Australia.

In recommending Mr. Glauert for this award, the selection committee was influenced not only by the individual merit of Mr. Glauert's publications, but by the extraordinarily wide field covered and the long and faithful service rendered to natural science in Western Australia.

Mr. Glauert's first papers appeared in 1909 in publications of the Geological Survey of Western Australia and since that date his contributions to science have included papers on stratigraphical geology, palaeontology, zoogeography, mammalogy, carcinology, herpetology, ornithology, and arachnology. In his position as Curator of the Museum, Mr. Glauert has never allowed his enthusiasm for any one branch of science to develop at the expense of the whole. In consequence, valuable collections have been built up in all branches of natural science and irreplaceable material has been preserved for the use of present day specialists as well as for future investigators. The value of these collections is exemplified by the long list of contributions to our own journal and other publications by world-acknowledged authorities, this work having been made possible only by the collecting enthusiasm and keen insight of Mr. Glauert.

In the field of popular science Mr. Glauert's work can never be truly assessed as he has been a constant stimulus to young and old alike and his contributions to the popular Press, his lectures and wireless talks have been a powerful influence in stimulating an interest in natural history and



MR. LUDWIG GLAUERT, Kelvin Medallist, 1945.

a true appreciation of Western Australian fauna and flora. Mr. Glauert's association with the Royal Society of Western Australia commenced in 1920. He was elected to Council in 1921 and during his subsequent unbroken term on that body he has held various offices including those of Librarian and President.

Publications for which Mr. Glauert has been responsible either wholly or in part include the following:—

1909: "Description of the crystalline rocks of the Phillips River Goldfields" (with E. S. Simpson). *Geol. Surv., W.A., Bull.* No. 35, pt. II.

1910: "*Sthenurus occidentalis.*" *Geol. Surv., W.A., Bull.* No. 36.
"A list of W.A. Fossils systematically arranged." *Ibid.*
"Fossil Flora of Western Australia." *Ibid.*
"The Geological Age and Organic Remains of the Gingin Chalk." *Ibid.*
"List of Fossils collected at Fossil Cliff." *Ibid., Bull.* No. 38.
"Brief Notes upon some Irwin River Rocks" (with E. S. Simpson). *Ibid.*

1911: "Further Notes on the Gingin Chalk." *Geol. Surv., W.A., Annual Rept. for* 1910.

1912: "The Mammoth Cave." *Records of W.A. Museum and Art Gallery,* Vol. I, pt. I.
"The Mammoth Cave" (cont.). *Ibid.,* Vol. I, pt. II.
"Determination of the Exact Localities where Cambrian fossils were collected by E. T. Hardman in 1884." *Ibid.*

1914: "Permo-carboniferous Fossils from Byro Station." *Ibid.*
"The Mammoth Cave" (cont.). *Ibid.,* pt. III.

1916: "Western Australian Stone Implements." *Man.,* Vol. XVI.

1921: "Notes on Western Australian Petrels and Albatrosses." *Journ. Roy. Soc. W.Aust.,* Vol. VII.
"Fish collected by the Government Trawler Penguin." *Ibid.*
"Pleistocene Fossil Vertebrates from Fitzroy River, W. Kimberley." *Ibid.*
"Notes on the teeth of *Nototherium mitchelli* Owen." *Ibid.*

1922: "Contributions to the Fauna of W.A., No. 1." *Ibid.,* Vol. VIII.

1923: "On a Cretaceous Echinid from Gingin." *Ibid.,* Vol. IX., pt. 1.
"Contributions to the Fauna of W.A., No. 2." *Ibid.*
"Contributions to the Fauna of W.A., No. 3." *Ibid.*

1924: "Notes on Fossil Plants from Mingenew and Irwin River." *Ibid.,* Vol. X.
"Contributions to the Fauna of W.A., No. 4." *Ibid.*
"Contributions to the Fauna of W.A., No. 5." *Ibid.*

1925: "Australian Scorpionidae, Part I." *Ibid.,* Vol. XI.
"The Scorpions (of Nuyts Archipelago) with descriptions of other localities in South Australia." *Trans. Roy. Soc., S. Aust.,* Vol. XLIX.

1926: "List of W.A. Fossils—Supplement No. 1." *Geol. Surv., W.A., Bull.* No. 88.

1927: "Further notes on the Gingin Chalk." *Journ. Roy. Soc., W.Aust.,* Vol. XII.

1928: "The Vertebrate Fauna of W.A., Part I." *Ibid.,* Vol. XIV.

1929: "Notes on the Habits of *Tarsipes spenserae.*" *Ibid.,* Vol. XV.

1930: "A New Victorian Scorpion *Cercophonius kershawi.*" *Victorian Naturalist,* Vol. 47.

1931: "Notes on the Banded Stilt with a Description of its Eggs" (with C. F. H. Jenkins). *Journ. Roy. Soc., W.Aust.,* Vol. XVII.

1934: "The Distribution of the Marsupials in W.A." *Ibid.,* Vol. XIX.

1938: "Western Australian forms of the Giant Petrel." *Ibid.,* Vol. XXIV.

1945: "A Western Australian Grass Owl." *The Emu,* Vol. XLIV.
"Some Western Australian Frogs." *The Aust. Mus. Mag.* Vol. VIII.

INDEX TO AUTHORS.

JOURNAL OF THE ROYAL SOCIETY OF WESTERN AUSTRALIA.

VOLUME XXXI.

1.—SOME WESTERN AUSTRALIAN LAMPROPHYRES.

By Keith R. Miles, D.Sc., F.G.S.

Read 12th September, 1944.

INTRODUCTION.

Very few occurrences of rocks of the lamprophyre family have yet been discovered in Western Australia and no detailed descriptions of the geology or field occurrence of any members of this family can be found in local geological literature. Petrographical details of one Western Australian lamprophyre only have so far been published. In recent years, however, quite a number of lamprophyres from scattered localities have come to the writer's notice and as a result he has been encouraged to compile the following petrographical notes upon the hitherto neglected Western Australian occurrences of some members of this interesting family of rocks.

The lamprophyres constitute a rather peculiar group of igneous rocks which occur most typically as dykes or other small intrusions (1). Because of their somewhat exceptional structure and composition members of this group do not fall readily into many accepted schemes of rock classification. Chemically the common types are characterised by medium to low silica content, a relative abundance of alkalies in the form of felspars and a relatively high content of ferromagnesian silicates. They are invariably fine-grained rocks, nearly always holocrystalline and may or may not be porphyritic in texture.

The lamprophyres are characteristically rich in brown mica, but in some varieties the place of biotite is largely taken by hornblende and/or augite, and consequently the commoner types are often distinguished as mica lamprophyres, hornblende lamprophyres or augite lamprophyres, depending on the predominant ferromagnesian mineral.

A further subdivision of the common types has been made by the distinction of the predominant felspar—orthoclase in one group and plagioclase in the other. The true nature of the felspars in these rocks is often very difficult to determine, however, owing to the abundance of secondary products or to the minute size of the individual crystals. Rosenbusch considers that the rocks of the first group, so far as composition is concerned, have affinities with syenite whilst the plagioclase lamprophyres are closely related to diorite.

A peculiar feature of the lamprophyres is that in the porphyritic members of the family, felspar seldom occurs as phenocrysts but only in the groundmass. The porphyritic character is invariably produced by two generations of the ferromognesian constituents which both in phenocrysts and groundmass have a distinct tendency to idiomorphism.

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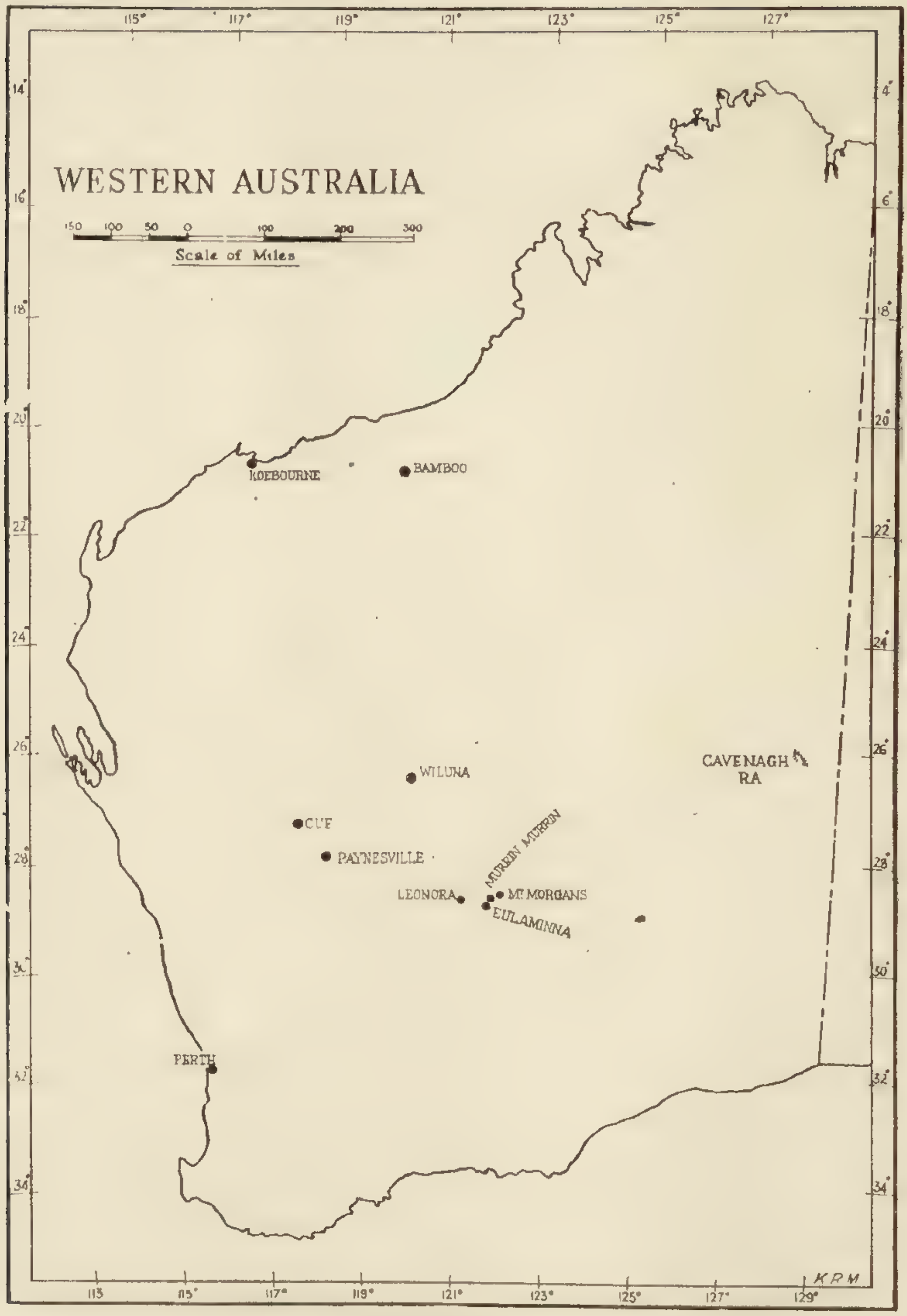
These and other typical features are to be noted amongst the 36 specimens of Western Australian lamprophyres examined and described in this paper. They come from a number of scattered centres—from the North-West at Bamboo Creek and Roebourne in the Pilbara District; and from numerous districts in the Central Goldfields, viz., Wiluna, East Murchison Goldfield; Cue and Payne-ville, Murchison Goldfield; Mt. Fouracre and Mt. Newman near Doyle's Well, Leonora district, Mt. Morgans district and Eulaminna-Murrin Murrin district, Mt. Margaret Goldfield. The principal centres are illustrated in the locality map (Text fig. 1).



TEXT FIG. 1.
Showing principal reference localities of lamprophyre occurrences in Western Australia.

Such information as could be gleaned regarding the field occurrences of these specimens indicates that to a large extent the rocks had been recognised in the field as dykes or similar small intrusive bodies. In most cases the rocks intruded appear to be representatives of the Older Pre-Cambrian

(Archaeozoic) of this State. At Wiluna, Cue and Mt. Morgans, and in the Eulaminna-Murrin Murrin district the lamprophyres are believed to intersect the auriferous greenstones or lode formations of the auriferous Older Greenstone Series. Here they are definitely post folding, and probably post-gold, and in all probability are Post-Granite in age. No field evidence has so far been found to indicate whether or not any of these lamprophyre intrusions were younger than Pre-Cambrian in age. To the writer's knowledge there is no record of lamprophyre dykes intruding the Proterozoic Nullagine Formation in the North-West of this State.

PREVIOUS LITERATURE.

There are available very few published records of the occurrence of rocks with lamprophyric affinities in Western Australia either amongst petrological literature or in accounts of the general geology of the State. No published descriptions of any field occurrences can be found.

In 1909 Simpson and Glauert in a description of the crystalline rocks of the Ravensthorpe District (2, pp. 26-7) under the heading "Rocks of Intermediate Basicity" described two groups of dyke rocks which they provisionally classed as "camptonites" and "kersantites," respectively. A careful re-examination of specimens so classified (2, pp. 42-3) reveals that none show many of the characters of the true lamprophyres as out-tonites," characterised by the presence of abundant amphibole (usually green hornblende or pale tremolite-actinolite) are rocks which according to modern nomenclature would be classed as epidiorites, several types of felspathic amphibolite and amphibolite schist, actinolite schist and a biotite-hornblendite. These rocks have probably been derived mainly from basic igneous types such as dolerites, basalts or basic andesites. The "kersantites" are characterised by the presence of essential brown biotite with frequent granoblastic gneissic structures and include such types as biotite amphibolite, biotite-hornblende granulite, biotite-tremolite schists, biotitic gneisses and what appears to be a magnetite-biotite hornfels. Some of these types probably represent the metamorphosed products of igneous, and others of sedimentary rocks. Montgomery in 1910 (3), in reporting on progress of mining in the Phillips River Goldfield, followed Simpson and Glauert's classification of these rocks.

The first authoritative account of a lamprophyre from Western Australia was given by J. A. Thomson in 1911 (4, pp. 300-301) when he described an "augite-hornblende lamprophyre, probably a camptonite" from the Cavenagh Range, Eastern Division. This specimen was one of a collection made by V. Streich, a member of the Elder Scientific Exploring Expedition of 1891-1892. Cavenagh Range (approx. Lat. 26° 10'S. Long. 127° 56'E.) is approximately 64 miles west of the South Australian border (Fig. 1). According to the mapping of Talbot and Clarke (5) this range consists of a comparatvely unmetamorphosed gabbro or dolerite intrusive into granite, and classed as pre-Ordovician (probably pre-Cambrian) in age.

Thomson's rock was described as dark grey, finely crystalline porphyritic, with phenocrysts of titaniferous augite and larger carbonate-chlorite pseudomorphs after an earlier mineral, olivine. The groundmass consisted of brown green hornblende prisms often with fibrous borders and kernels of augite, felspar, probably albite, in short laths or radially grouped forms, scattered nests of epidote associated with chloritised hornblende and carbon-

ates, plentifully scattered magnetite granules and accessory sphene. Thomson recorded his belief that this was "the first rock of this class so far found in Western Australia," and in a footnote remarked that "the rocks described as camptonites by Simpson and Glauert .. appear to the writer to be really contact-altered amphibolites." (4, 301.) Thomson could give no details of the field occurrence of his rock.

In 1925 E. de C. Clarke, in his bulletin on the field geology and broader mining features of the Leonora-Duketon district, Mt. Margaret Goldfield, referred to later basic dykes intrusive into both greenstone and granite and recorded that "these dykes are unaffected by dynamic metamorphism" in which lies their fundamental difference from the older though often somewhat similar looking (auriferous) greenstones (6, p. 37). In an appended classified list of specimens of these later basic dykes examined by the Petrologist (R. A. Farquharson) (6, p. 58) are included four rocks identified as lamprophyric in character—two (1/2190, 1/2192)* being determined as "very felspathic and acicular epidiorites, of camptonitic composition and structure," one camptonite (1/2211) and one "mica-lamprophyre but near vogesite" (1/2248). No further petrographic details of these rocks have been published. These rocks will be further described when the lamprophyres from the Mt. Margaret Goldfield are dealt with in the following section.

Detailed geological surveys of the Eulaminna-Murrin Murrin district in 1940-41 by R. A. Hobson have revealed that lamphrophyre dykes are relatively abundant in this region, and although no details of their occurrence have yet been published they are included in a tabular classification of rock types from the area published in a summary progress report in 1940 (7).

DESCRIPTION OF ROCKS.

In order to facilitate description of the different rocks examined and to submit such notes of their field occurrence as are available in as systematic a manner as possible, they have been arranged according to the locality of their occurrence in the State, going from north to south. As will be seen, in many cases no details of the occurrence of individual specimens is available.

NORTH-WEST DIVISION.

Bamboo Creek, Roebourne.

Two specimens having affinities with the lamprophyres both in mineral composition and microstructure come from the Pilbara District of the North-West. They were both collected by T. Blatchford during investigations in the district in 1912 (8). The first (12545) is registered as "dyke, Bamboo Creek," and no other details of field occurrence are available. According to Maitland (9) Bamboo Creek mining centre consists essentially of steep dipping Archaean (greenstone) schists and laminated chert intruded by granite, faulted and overlain to the east by gently dipping sedimentary rocks and interbedded felsitic lavas, presumably of Nullagine age.

In hand specimen this is a very dense fine-grained grey coloured rock in which can be distinguished occasional scattered clear felspar phenocrysts up to 2 mm. in diameter.

*All following numbers except those preceded by the letter U refer to register or field numbers in the Geological Survey Rock Collection. These preceded by U come from the General Rock Collection of the Department of Geology, University of W.A.

In thin slice this is found to consist largely of a fine, even-grained aggregate of interlocking felspar laths and interstitial shredded, chlorite pseudomorphs after biotite, enclosing occasional phenocrysts of cloudy altered felspar (probably acid plagioclase), and smaller shredded plates of bleached biotite. Secondary epidote in granules replacing felspar, associated with the chlorite and also in scattered groups of subhedral plates is common. Extinction angles indicate that the felspar laths of the groundmass are largely basic oligoclase (Ab_{73}) though some of the more cloudy laths may be orthoclase (parallel extinction in many sections and refractive index less than balsam). Sphene is a common accessory and several patches of interstitial quartz occur. This slice includes an irregular patch of introduced sulphide (pyrite) surrounded by epidote crystals.

Although it is not typical of the family this rock is in all probability an altered form of original mica lamprophyre near kersantite.

The second specimen (12579) comes from the old Fortune Copper Mine, Glenroebourne in the Roebourne district. According to Woodward (10) the fundamental rocks in this district consist mainly of ancient basic igneous types—dolerites and gabbros with intrusive hornblende granite. Blatchford marked this specimen as a "dyke rock," whilst another specimen marked "country rock" from the same locality proves to be a uralitised quartz gabbro. (12579) is a fine-grained reddish brown coloured rock through which are scattered plates of dark green mica up to about 3 mm. diameter, giving it a very speckled appearance. The mica has a tendency to orientation in one plane, giving the appearance of a rude schistosity.

In thin slice the mica phenocrysts are seen to be green pleochroic biotite with Z = deep green, Y = deep yellowish green, X = pale greenish yellow: $Z < Y > X$. They often enclose granules of iron ore, zircons with pleochroic haloes, and contain interlaced needles of rutile. Other phenocrysts consist of a few irregular pale yellowish green chloritic areas, whose centres are largely replaced by carbonates—probably representing original augite or possibly olivine.

The ground mass consists of an interlocking aggregate of felspar laths—twinned laths are albite (Ab_{90}), though some untwinned material may be orthoclase—shredded green biotite, and abundant granular carbonate plentifully sprinkled with octahedra of magnetite. In addition scattered through the ground are fairly numerous irregular areas up to 1 mm. diameter filled with clear quartz or calcite, or both, which possibly represent amygdales.

This is a typical mica lamprophyre which, judging from the abundance of plagioclase felspar, may be classed as a kersantite.

The Central Goldfields.

East Murchison Goldfield—Wiluna.

During the University vacations of 1935-36 the writer, while employed on the Wiluna Gold Mine collected specimens of a fresh, dark, brown-looking dyke rock from the south side of the plat at the main shaft, 1,000 ft level, which he later determined as a camptonite. The country rocks of the Wiluna Gold Mine consist of a series of vertically dipping amphibolite and chlorite schists all more or less carbonated, representing original interbedded basic flows, including beds of pillow lavas of Pre-Cambrian (Older Greenstone)

age. These rocks have been intruded by dykes or sills of felsite, sheared along major zones with the production of graphitic shear walls, and then largely replaced by carbonates along the shear zones to form calc schists. Sulphides—arsenopyrite, pyrite, stibnite, etc., have been introduced together with gold, with the carbonating solutions. Post-gold dykes of black basaltic dolerite are known to intersect the country in the Wiluna Gold Mine.

The writer has no direct evidence that the rock (U15295, U18853) to be described below forms portion of a post-gold dyke but the absence of any signs of carbonatisation within it and its unaltered appearance amongst the carbonated, chloritised and uralitised country rocks indicate a younger intrusion. No evidence is available as to the relative ages of this rock and the basaltic dolerite.

This rock (U15295) is dense fine-grained, dark red brown in colour with irregular greenish areas and is sprinkled with glistening tiny black needles up to 2 mm. long. In another specimen (U18853) the needles are far less distinct and the greenish areas are more prominent. The rock is sprinkled with rare crystals of pyrite.

The typical form and mineral composition of (U15295) is illustrated in Text Fig. 2A. Euhedral needles of hornblende are scattered in random orientation, together with a few chloritised, epidotised, carbonated remnants of colourless augite plates, through a very fine-grained groundmass of minute interlocking laths of plagioclase sprinkled with granules of magnetite, occasional cloudy carbonate areas, a little granular epidote, and scattered crystals of pyrite.

The hornblende crystals are distinctly pleochroic, with X = yellow, Y = yellow brown, Z = greenish brown; absorption Z = Y > X; Y = b, $Z \wedge c = 20°$; (—), 2 V large (about 85°). This is a true hornblende. Basal sections show strongly developed (110) faces often to the exclusion of (010). Twins on (100) are common with occasional central darker zones. The areas of original pyroxene are all more or less completely replaced by pseudomorphs of pale green chlorite often with yellow epidote or granular carbonate.

The felspar laths frequently show albite twinning with sections cut normal to the twin plane having extinction angles up to 12°. Refractive index is either less than or about equal to canada balsam thus indicating albite (Ab_{90}). Under high powers the groundmass is seen to be crowded with minute hornblende and probably some apatite needles, thus making an estimate of the approximate mineral composition of the rock extremely difficult. Approximate figures based on measurements under low powers are:—Felspar, 55-60%; hornblende, 30-35%; epidote and chlorite, pseudomorphs 6%; pyrite 2%; other accessories (magnetite, carbonates, apatite, etc.) 2%. This rock is an excellent example of a hornblende lamprophyre-variety camptonite.

(U18853) is a coarser-grained specimen which contains phenocrystal plates of euhedral chloritised biotite, whilst the hornblende needles are largely replaced by shredded chlorite and magnetite granules. The felspar laths are frequently grouped in radiating aggregates, whilst apatite in short stumpy crystals is an abundant constituent. Pyrite is plentifully sprinkled throughout, granular carbonates are common and a little vein quartz can be seen.

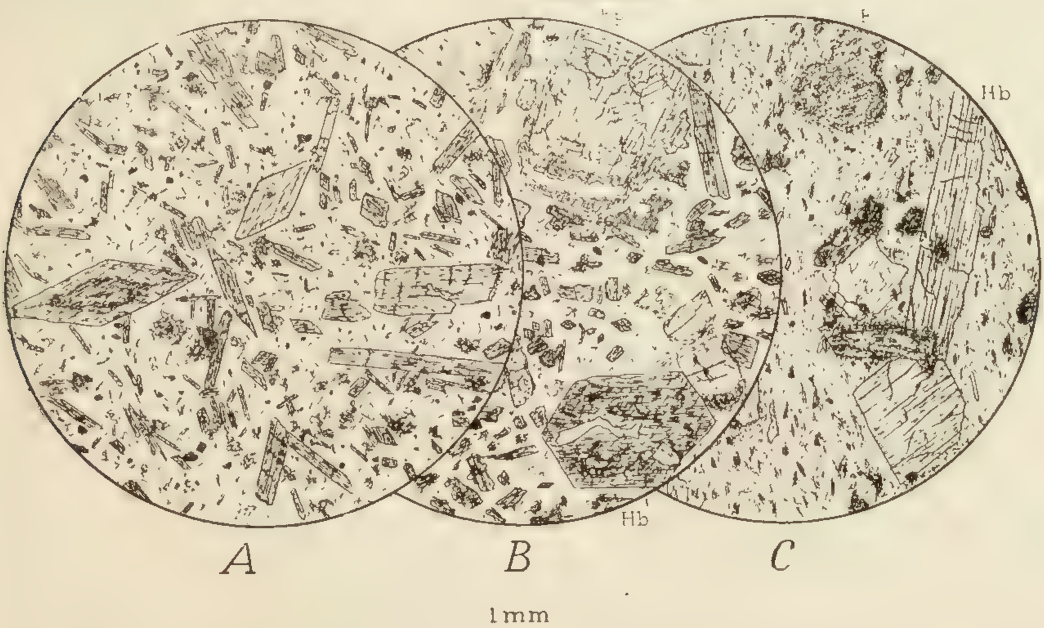
Murchison Goldfield.

(a) *Cue.*

Specimens of a lamprophyric dyke rock were recognised and collected by Dr. R. T. Prider from the core of a bore drilled in 1935 by Anglo-Australian Gold Development Company for Day Dawn Gold Mines on the old Lady Forrest Lease, about a mile south-west of Cue townsite. The country here consists of epidiorite-amphibolite (Older Greenstone Series) intruded by gabbros, and granite and porphyry dykes (11).

Specimens examined were taken from Bore No. 2 at depths of 1,012 ft. (U13437), 1,013 ft. (U12436), 1,014 ft. (U13438) and at 1,014 ft. 3 inches (12437). The last specimen showed the contact between the lamprophyre dyke and the adjoining country rock. From information kindly supplied by Dr. Prider it would appear that the total length of dyke contained in this bore core was about 2 ft. 7 inches. The angle of intersection at the lower contact was approximately 35°, so that the dyke was probably about 18 inches wide. Dr. Prider also reported that the end of Bore No. 2 at 1,021 ft. 2 in. penetrated 2 inches into a second lamprophyre dyke. No specimen of this occurrence was available, however.)

All specimens were greenish grey coloured, medium-fine grained and porphyritic with distinct whitish phenocrystal areas (?felspar) up to 2.5 mm. diameter.



TEXT FIG. 2.—Hornblende Camptonites, Murchison.

A. (U15295). From 1,000 ft. level Main Plat, Wiluna G.M., showing euhedral hornblende phenocrysts in a fine-grained albite-hornblende groundmass with scattered magnetite and pyrite grains (black). A few epidote-chlorite pseudomorphs after pyroxene occur in other parts of the slice.

B. (U13437). From No. 2 Bore, Daydawn G.M., Cue, at bore depth 1,012 ft., showing euhedral hornblende phenocryst (Hb) enclosing felspar and a nest of epidote (Ep) pseudomorphous after phenocrystal felspar. Epidote also builds smaller plates and hornblende forms a second generation of small needles. The clear plate in the top left-hand corner is chlorite.

C. (U12437). From the same dyke, No. 2 Bore at 1,014 ft. 3 in. at its chilled contact with epidiorite wall rock. Shows clear phenocrystal hornblende (Hb) and cloudy saussuritised felspar (F) in an extremely fine-grained felted groundmass.

Under the microscope (U13437) was seen to be the most coarsely grained, the others showing a gradational decrease in grain size of the groundmass as the contact is approached. A slice cut from (U12437) right at the contact shows the groundmass as a cryptocrystalline aggregate with a distinct fluxional arrangement of the minerals. The coarse specimen, and this contact specimen are illustrated in Text fig. 2 B and C.

The phenocrystal minerals consist of euhedral greenish yellow to brown hornblende in tabular crystals similar to that of the Wiluna rock, clear plates or cloudy granular aggregates of epidote or zoisite pseudomorphous after phenocrystal felspar, and here and there associated with colourless uralite or chlorite in pseudomorphs after pyroxene. The groundmass consists principally of prisms of hornblende and cloudy granular epidote or zoisite and euhedral laths of clear colourless felspar—twinned individuals being albite—oligoclase (Ab_{88-90})—with possibly some orthoclase. The ground is sprinkled with rare magnetite granules and a little pyrite. One round grain of resorbed quartz with a reaction border of amphibole cystallites was noticed in (U13437). As the border of the dyke is approached the groundmass generation of hornblende becomes reduced to an irresolvable felted aggregate of minute euhedral needles, whilst the phenocrystal felspar instead of being replaced by clear epidote consists of a dark cloudy aggregate of saussurite (see Text fig. 2C).

This is a typical narrow dyke rock—camptonite showing a chilled margin at its contact with the invaded uralitic epidiorite country.

(b) *Paynesville.*

This specimen (1/3730) was collected by A. G. D. Esson in November, 1924, during the course of his survey of the Paynesville district, the results of which are contained in an unpublished report (12). The specimen came from the flats about two miles west of East Mt. Magnet Trig., which lies some 10 miles south-south-west of Paynesville centre. The rocks of this area have been mapped by Esson as greenstone (epidiorite) presumably of the Older Greenstone Series, which has been invaded by bodies of quartz porphyry, dykes of keratophyre and quartz veins, and capped by ironstone gravel.

(1/3730) is a fresh dark green-grey medium to fine-grained rock, glistening with plates of grey-black ferromagnesian minerals ranging from less than 0.2 mm. up to about 1.4 mm. in diameter.

Under the microscope the ferromagnesians are seen to consist of a few tabular plates of colourless augite (optically + ve, 2V about 70°, $Z \wedge c = 44°$) averaging about 0.8 mm. x 0.4 mm., but ranging up to 2 mm. x 1 mm. and showing all stages of alterations to greenish uralitic amphibole; several fairly large scattered laths of green to yellow pleochroic biotite up to 1.5 mm. long and numerous smaller plates rather shredded and clouded by granules of separated iron oxide; very abundant needles and laths of green hornblende from 0.1 up to 1 mm. long, showing various degrees of alteration to chlorite and epidote and with inclusions of ore rimmed by iron oxide; and a few scattered granular aggregates of epidote. The original euhedral form of the hornblende is often masked by the secondary alteration products.

The ferromagnesians are enclosed in a clear groundmass of cryptocrystalline felspar often in minute semi-radiating aggregates whose nature is not determinable, though the refractive index (about that of balsam) suggests a soda-rich plagioclase. The felspars are here and there clouded by granular carbonate. The groundmass is sprinkled with granules of magnetite, abundant needles and well formed tabular crystals of apatite and occasional accessory grains of sphene.

This is a typical hornblende lamprophyre, probably camptonite.

Mt. Margaret Goldfield.

This goldfield has so far yielded by far the greatest number of specimens of lamprophyres. These have come from three separate districts—Leonora, Mt. Morgans and Eulaminna-Murrin Murrin. The bulk of the known occurrences are in the vicinity of Murrin Murrin, and most of the specimens were collected by R. A. Hobson during the course of the re-survey of portion of the Mt. Margaret Goldfield, 1940 and 1941. The lamprophyres have been recognised as some of the youngest intrusives in this district and post folding in age, though Hobson still considers them to belong to the Pre-Cambrian (7).

(a) *Leonora District.*

Two specimens (1/2190, 1/2192) collected by Clarke from Mt. Fouracre near Doyle's Well, and from the Victory lease west of Mt. Newman, respectively, were classed by Farquharson as camptonitic epidiorites (6, p. 58) as mentioned above.

These are both grey coloured, medium-fine, even-grained rocks. (1/2190) shows cataclastic structure under the microscope, consisting of needle tufts of pale green hornblende with a little scaly brown biotite intergrown with even-granular tabular plates of basic oligoclase showing peripheral granulation, and some interstitial quartz. Accessory minerals are sphene, with minor apatite and magnetite. (1/2192) is slightly coarser-grained with the amphibole tabular, idiomorphic and the felspar shows little signs of cataclasis. Interstitial minerals include quartz and chlorite.

These two rocks, though having the approximate mineral composition of camptonite have the structure of slightly crushed fine-grained diorite.

Two other specimens from the Leonora district, however, also collected by Clarke in 1918 show close affinities with the mica lamprophyres. These are (1/2006) from the "Blue Spec" workings and (1/2015) from the Mt. George group (east of the old Aukland Gold Mine), some nine miles north of Leonora.

The first is a rather weathered specimen—grey-white coloured, fine even-grained, and consists of shredded aggregates of pale brown biotite enclosed in a groundmass of radiating brushes of felspar (apparently albite), with a few interstitial grains of quartz. The felspar areas are crowded with minute interlaced colourless needles of apatite, visible only under high powers. (1/2015) is a dark coloured medium-fine-grained rock sprinkled with glistening plates of brown biotite up to 1.5 mm. diameter. In thin slice this was seen to contain two generations of biotite—in phenocrystal plates strongly pleochroic with $X =$ yellowish brown, $Y =$ greenish brown and $Z =$ very dark brown, $X < Y < Z$, and with resorbed borders; and in small very abundant euhedra laths intergrown with the groundmass felspar (albite) which is frequently in radiating groups of laths. Accessories are a few grains of quartz, a little granular iron ore and scattered pyrite. This rock is a normal mica lamprophyre (kersantite).

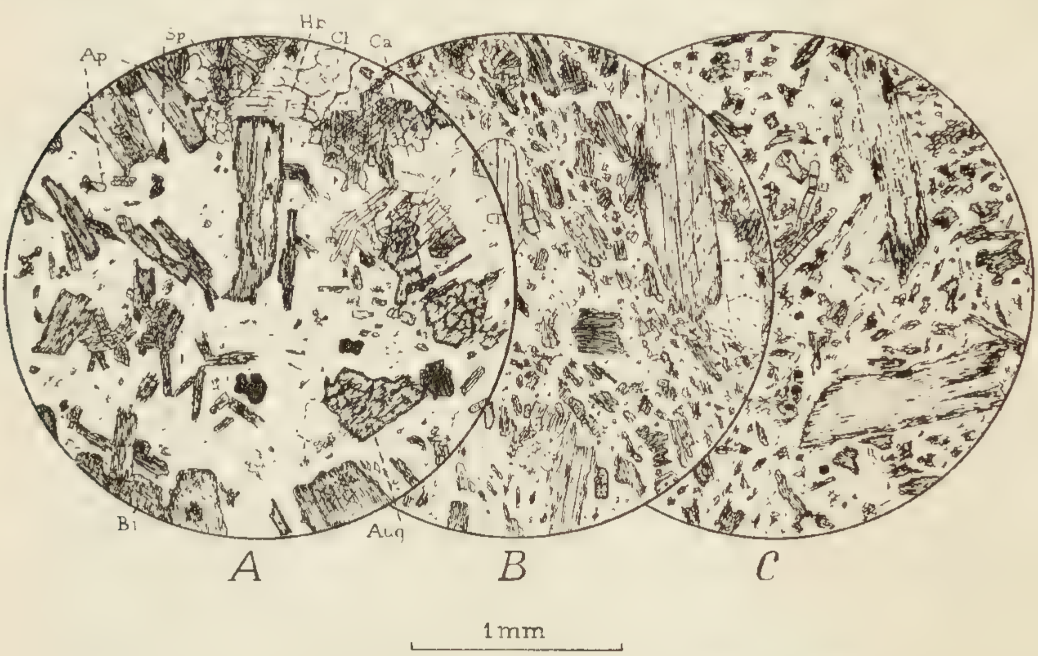
(b) *Mt. Morgans District.*

Several specimens of the so called "mica bars" from the late Westralia-Mt. Morgans Gold Mine at Mt. Morgans have been collected from time to time. These "mica bars" are said to cut through the lode. Specimen (5684) was obtained by C. F. V. Jackson in 1904, (1/2248) by Clarke in the course of the Leonora-Duketon Survey (6, p.58) and (L315) was collected by the

present writer in 1938. The last specimen came from the main drive of the 200 ft. level, about 80 feet north of the main shaft. No further details of the exact locations of the other specimens are available.

All three rocks are mica lamprophyres which show traces of a rude schistosity due to a slight orientation of the biotite phenocrysts. Specimen (L315) is considerably bleached and oxidised but (5684) is a fresh dark grey rock sprinkled with shining black biotite plates up to 2.5 mm. in diameter, and scattered crystals of pyrite. In thin slice the rough orientation of the biotite phenocrysts is noticeable, see Fig. 3 B. These are intensely pleochroic X = pale yellow, Y = deep brown, Z = deep red brown. Moulded upon the phenocrysts or associated with the scaly biotite of the groundmass is calcite in clear plates or granular aggregates. The felspar of the groundmass is mainly in cryptocrystalline aggregates too small for identification but there are areas of larger radiating aggregates of plagioclase (albite) showing lamellar twinning with extinction angles up to 10°.

Specimen (1/2248) is distinctly coarser grained than the last specimen, with the glistening black phenocrysts of biotite up to 3.5 mm. The grey granular groundmass is relieved with crystals of pink felspar.



TEXT FIG. 3.—Mica Lamprophyres, Mt. Margaret Goldfield.

A. (1/2248). Augite minette from late Westralia-Mt. Morgans G.M., Mt. Morgans, showing biotite flakes with sagenite (Bi), remnants of augite (Aug), a little shredded chlorite (Cl) and a hornblende plate (Hb) set in a clear felspathic groundmass (predominantly orthoclase) with some calcite (Ca). The black opaque grain is pyrite and other accessories include apatite (Ap) and sphene (Sp).

B. (5684). From the same locality, showing biotite flakes in two generations with granular calcite in a cryptocrystalline felspar ground. Probably kersantite.

C. (L632A). Kersantite from a shaft dump about half-mile south of Murrin Murrin Siding. Shows phenocrysts of bleached chloritic biotite in a groundmass of clear albite-oligoclase laths studded with biotite shreds, magnetite, pyrite and carbonates, and broken needles of apatite in the centre of the field.

The microscopic appearance of this rock is illustrated in Text fig. 3A Chief ferromagnesian is biotite—mostly green-yellow with X = greenish yellow, Y = greenish-brown, Z = deep brownish-green, though some of the larger phenocrysts have cores of yellow-brown colour similar to the biotite in (5684). Some plates show interlacing sagenitic rutile due to the separation out of their titania content, and most have darker resorption borders.

Pale greenish augite having original euhedral forms but now partially replaced by fibrous green amphibole is a lesser but nevertheless abundant constituent, and a few separate prisms of euhedral green chloritic hornblende can also be seen. These minerals are enclosed in a ground of fairly coarse clear felspar plates which show simple twinning and are optically—ve with refractive indices distinctly less than balsam, hence are orthoclase. Apatite in short stumpy crystals and irregular granules, and small diamond-shaped crystals of sphene are abundant accessories. Small quantities of carbonate (calcite) in anhedral grains often enclosing granular apatite are scattered throughout the slice and clear twinned oligoclase occurring in a few rare small grains interstitial between orthoclase or biotite plates or associated with carbonates, is obviously one of the last formed minerals.

This rock was classed by Farquharson as a "mica lamprophyre near vogesite" (6, p. 58) but taking into account the predominance of mica amongst the ferromagnesians it may be preferable to call it an augite-minette.

Specimen (1/2082) collected by Clarke and said to come from 7½ miles north-east of Mt. McKenzie, Mt. Morgans, is a dark greenish schistose chloritic rock, which is reddish coloured on weathered surfaces. In thin slice it is revealed as a chloritised hornblende lamprophyre which has undergone dynamic stress. Ragged oriented shreds of chlorite pseudomorphous after hornblende are scattered through a ground of granulated felspar—probably both orthoclase and sodic plagioclase. Accessory apatite and pyrite are common and magnetite and carbonate granules are also present.

(c) *Eulaminna-Murrin Murrin District.*

Of the 19 specimens of lamprophyres so far collected from this district, 11 can be classed as hornblende or augite lamprophyres and the remainder mica lamprophyres.

Specimens of the former group include (1/2211) collected by Clarke from 140 chains north of Eulaminna, marked "dyke in greenstone" (6, p.58); (L808) from 2½ miles due south of Eulaminna, (L635), (L644), (L725), (L728), (L731) from within a radius of two miles of Murrin Murrin either to the south or east, (L724) from 3½ miles south-east of Murrin Murrin Siding, and (L787), (L788) from the vicinity of the Pearl Shell leases some 3½-4 miles north-west of Murrin Murrin, all collected by R. A. Hobson in 1940; and (L299) collected by the present writer from a narrow dyke cutting through coarse porphyritic gabbro at a point half a mile due north of Murrin Murrin Siding.

Of Hobson's collection all specimens except (L635), (L724), which came from mine dumps and (L808), were broken from the outcrops of small dykes intrusive into bodies of amphibolite, basic lavas or dolerite (considered to be representative of the Older Greenstones) which form portion of the country rocks of the district.

(1/2211) is a typical hornblende lamprophyre—fresh medium grained, grey coloured, sprinkled with abundant black amphibole needles and less frequent tabular greenish crystals of pyroxene. The amphibole is euhedral brown hornblende similar in optical character to that in the Wiluna camptonite described above. The needles range from less than 0.2 mm. up to 2 mm. in length. Euhedral colourless augite occurs in short tabular plates in varying degrees of alteration to fibrous chlorite, individual crystals being developed up to 1 mm. in diameter. The predominant felspar is slightly

cloudy, rarely twinned albite-oligoclase (Ab_{86}-Ab_{90}) in well formed laths whilst minor quantities of orthoclase showing carlsbad twins, also occur. Accessory apatite is present in minute colourless needles whilst iron oxide, chlorite, etc., are common secondary products. This rock is a normal camptonite.

TEXT FIG. 4.—Augite and Hornblende Lamprophyres, Mt. Margaret Goldfield.

A. (L644). Augite camptonite from a dyke 70 chains south of Murrin Murrin Siding. Contains clear phenocrystal augite (Aug) showing marginal alterations to amphibole and chlorite and yellow epidote grains (Ep.) in a groundmass of subradiating plagioclase laths with interstitial chlorite.

B. (L635). Hornblende camptonite from a shaft dump, Murrin Murrin, showing a phenocryst of bleached brown biotite (Bi) and two generations of hornblende (Hb). Phenocrystal augite and some epidote occur in other portions of this slice.

C. (L808). Augite-hornblende camptonite from a dyke 2½ miles south of Eulaminna, showing euhedral augite (Aug) phenocrysts and smaller laths and needles of hornblende (Hb). The felspar of the groundmass is albite.

D. (L299). Hornblende camptonite from a dyke half-mile north of Murrin Murrin, showing fibrous hornblende in clustered phenocrysts pseudomorphous after augite, and a radiating aggregate of epidote (Ep), set in a groundmass consisting of shredded green hornblende and clear sodic plagioclase laths.

Specimens (L644), (L635), (L808) and (L299) are illustrated in Fig. 4 A-D. The first is a greyish green medium-fine-grained porphyritic rock with phenocrysts of usually fresh, clear, colourless augite plates which show occasional slight alteration, both marginal and along fractures, to pale green chlorite and uralite. This augite is non-pleochroic, optically positive with a moderately large optic axial angle (about 70°); $Z \wedge c = 44$-$45°$. Prismatic sections have one well developed cleavage parallel to c, whilst parallel extinction on basal sections indicate that (100) and (010) are the predominate cleavages. The only other ferromagnesian mineral present in any quantity is epidote in anhedral bright greenish yellow granules (pistachite). The felspar (albite) occurs in the groundmass in radially grouped aggregates of long laths with occasional small interstitial grains of quartz. Small areas of carbonates are scattered through the ground. Apatite in short needles is an important accessory. This is an augite camptonite notable for the entire absence of amphibole, except perhaps for some secondary needles associated with the chlorite.

(L635) is a dark grey rock slightly coarser-grained than (L644). It contains phenocrysts of rather bleached-looking brown biotite showing marginal resorption and alteration to green chlorite with the separation of iron oxides, fresh green-brown hornblende, and remnants of colourless augite in

process of alteration to green scaly chlorite and tremolite. Euhedral hornblende also occurs in a second generation of small needles scattered through a ground of sodic plagioclase with a little orthoclase, and scattered areas of secondary carbonate. This can be classed as a hornblende camptonite with minor augite and biotite.

(L808) is dark green, dense and finer-grained than the previous specimens and contains euhedral phenocrystal augite occasionally showing resorption borders, set in a groundmass of euhedral brown hornblende and cloudy lath-like albite. Here and there are scattered clear rounded areas consisting largely of radiating plagioclase occasionally enclosing grains of epidote and pyrite. This rock is an augite-bearing hornbende camptonite.

(L299), a dark green fine-grained rock contains hornblende in two generations—phenocrystal green, rather fibrous plates often pseudomorphing pyroxene, and aggregates of shredded thin laths. Yellow epidote of phenocrystal size is the only other ferromagnesian, and this also appears to be a replacement mineral. The felspars in the groundmass are sodic plagioclase, often in radiating sheaves, with here and there small clear rounded areas filled with a partially resorbed albite plate, or with aggregates of slightly coarser crystals. This is a hornblende camptonite.

Of the remaining specimens in this group (L725), (L728) and (L731) are very fine-grained greenish-black hornblende camptonites. The first contains phenocrystal chloritised augites up to 1 mm. diameter, carbonate and quartz in an acicular hornblende-plagioclase groundmass, whilst in (L728) scattered small rounded areas of green serpentine with centres of granular epidote suggest the remains of original early-formed olivine, enclosed by sheaves of interlacing brown green hornblende needles. The predominant felspar is oligoclase. (L731) shows a distinct orientation (flow structure) of the short idiomorphic felspar laths in a groundmass which also contains shredded green chlorite replacements of hornblende, abundant carbonate granules and a little interstitial quartz. Judging from the predominant +ve optical character the bulk of the felspar is albite, though some orthoclase is probably present. The groundmass encloses rare areas of granular epidote and chlorite probably pseudomorphous after a pyroxene.

Specimens (L724), (L788) and (L787) are all distinctly porphyritic, the first two being greenish and the last brownish coloured. (L788) and (L787) have idiomorphic phenocrysts of brown hornblende up to 12 mm. long. In (L724) the principal phenocrysts are augite plates up to 2 mm. diameter usually completely uralitised, and scattered roundish areas up to 0.4 mm. diameter of green serpentine rimmed with magnetite, marking original olivines. Groundmass contains greenish-brown biotite, green chlorite and amphibole shreds (largely from augite) with plagioclase in blurred outlines. Magnetite granules are also abundant. This is an altered augite camptonite which originally contained a considerable proportion of olivine.

(L788), (L787) are both augite-hornblende camptonites, the former containing fresh brown-yellow hornblende and chloritised, carbonated augite phenocrysts with scattered areas of quartz and carbonates in a very fine-grained groundmass. The latter consists of euhedral phenocrysts of green-brown hornblende and pale green augite with smaller yellow epidote, green chlorite and rare laths of sodic oligoclase, in a ground of sheaf-like idiomorphic plagioclase and short hornblende laths with a little interstitial quartz, and accessory magnetite, apatite and pyrite.

Of the mica lamprophyres from the Eulaminna-Murrin Murrin district, specimen (1/2229) was obtained from the Main Shaft dump on the old Anaconda Copper mine at Eulaminna by Clarke in 1918 and (L332) was collected by the writer in 1938 from a narrow dyke cutting coarse porphyritic gabbro at about two and a half miles north of Murrin Murrin. The remaining six specimens (L631), (L632A), (L637), (L638), (L665) and (L669) were collected by R. A. Hobson. Of these all except the last came from the dumps of shafts on leases lying to the immediate south or south-west of Murrin Murrin Siding. (L669) came from a dyke, near (L644), intruding a small area of quartz dolerite at 70 chains due south of Murrin Murrin.

All of these rocks are greenish-grey in colour—except (L669) which is brown—and in all specimens shining flakes of mica, dark green and changing to silvery grey on weathered surfaces, up to 8 mm. in diameter are scattered through a fine-grained ground. Many specimens show a rude schistosity owing to orientation of the mica phenocrysts.

The phenocrystal mica is invariably in a very bleached condition and the original brown colour is seldom seen. It is occasionally altered to pale green chorite with a dark rim of iron oxide. This is illustrated in Fig. 3C of a typical specimen (L632A). Frequently plates sliced parallel to the base show interlaced rutile needles in typical sagenite structure. In many of the specimens the felspathic groundmass is turbid crowded with secondary products—shredded chlorite, carbonates, iron oxides—and the true nature of the felspar cannot be determined, but in (L632A), (L669) it is predominantly albite-oligoclase $Ab_{(88.90)}$. Most specimens contain little interstitial quartz in the groundmass which is usually sprinkled with magnetite grains. Epidote builds phenocrystal aggregates in (1/2229) and is a decomposition product of the mica in (L669). Apatite is a common accessory in most specimens and occurs in typical cross-fractured needles in (L632A). It is particularly abundant in (L669) and builds stumpy euhedral crystals, one of which measured 0.5 mm. long by 0.2 mm. wide.

Specimens (L631), (L637), (L638) and (L665) are in highly chloritised and carbonated condition and can only be classed as altered mica lamprophyres, but (1/2229), (L332), (L632A) and (L669) are normal kersantites.

SUMMARY.

Some 36 specimens of lamprophyres from widely scattered centres in the North West and in the Central Goldfields have been examined and described. They comprise many of the common types of mica, hornblende, and augite lamprophyres including kersantites, an augite-minette, hornblende and augite camptonites, some of which show a certain amount of secondary alteration.

Such field information as is available indicates that the lamprophyres are everywhere intrusive into the older metamorphic rocks of the Pre-Cambrian, viz., the Older Greenstone Series, but there is no evidence to show that they are anywhere contemporaneous with or younger than Nullagine (Proterozoic) Age.

The Eulaminna-Murrin Murrin district of the Mt. Margaret Goldfield has proved the most fruitful area for lamprophyre dykes so far found in this State, specimens having been collected from some 19 localities within this area.

ACKNOWLEDGMENTS.

The writer is indebted to Professor E. de C. Clarke for permission to examine slides and specimens from the Rock Collection of the Geology Department, University of W.A., and to the Government Geologist, Mr. F. G. Forman, for the use of material from the Geological Survey Collection.

REFERENCES.

(1.) Harker, A., 1923. Petrology for Students. Cambridge, p. 137 *et seq.*

(2.) Simpson, E. S., and Glauert, L., in Woodward, H. P., 1909. *Geol. Surv. W.A.* Bull. 35, pp. 26-7, 42-3.

(3.) Montgomery, A., 1910. Report on Progress of the Phillips River Gold and Copper Mining Field. Dept. Mines, Perth. By auth. pp. 9-16, etc.

(4.) Thomson, J. A., 1911. Rock-specimens from Central and Western Australia collected by the Elder Scientific Exploring Expedition of 1891-92. *Trans. Roy. Soc., N.S.W.* Vol. 45, pp. 292-317.

(5.) Talbot, H. W. B., and Clarke, E. de C., 1917. *Geol. Surv. W.A.* Bull. 75, Plate III.

(6.) Clarke, E. de C., (with R. A. Farquharson), 1925. *Geol. Surv. W.A.* Bull. 84.

(7.) Hobson, R. A., 1941. Ann. Prog. Rept. *Geol. Surv. W.A. for* 1940, p. 11.

(8.) Batchford, T., 1913. *Geol. Surv. W.A.* Bull. 52.

(9.) Maitland, A. G. 1908. *Geol. Surv. W.A.* Bull. 40, pp. 49-51, and Geol. Sketch Map. Pl. 4.

(10.) Woodward H. P., 1911. *Geol. Surv. W.A.* Bull. 41, p. 102.

(11.) Woodward, H. P., 1907. *Geol. Surv. W.A.* Bull. 29, Pt. I. (Geol. Sketch Map of Cue).

(12.) Esson, A. G. D., 1925. An Investigation into the Geology of Paynesville Centre and District, Murchison Goldfield. (Unpublished Report of Geol. Surv. W.A.).

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2.—SOME CHAETOGNATHA FROM WESTERN AUSTRALIA.

By J. M. THOMSON, B.Sc.

Read: 11th November, 1944.

The Chaetognatha of the Australian region have been little reported upon. Johnston and Taylor (1919) worked on material from the coasts of New South Wales and Southern Queensland. Tokioka (1940) recorded several more species from the vicinity of Sydney. The only West Australian record of the group is that by Ritter-Zahony (1910) who identified the species present in a small collection made at Shark Bay by the Hamburg Museum Expedition.

This paper records the species found in a few hauls made at Nornalup, South-western Australia in November 1939, and at Cockburn Sound near Fremantle in April, May and July 1941, by members of the Biology Department of the University of Western Australia.

These hauls were all made close in-shore. In general Chaetognatha are oceanic rather than neritic, so that poor samples are to be expected in these hauls. Two hauls made at Nornalup contained a total of only nine specimens. Of the nine hauls from Cockburn Sound, five contained no Chaetognaths, while the remaining four provided twenty-five specimens.

No fully mature examples were found, most of the specimens showing little or no development of the gonads. Russell (1936) suggested that the explanation of the abundance of immature and scarcity of adult Chaetognatha in the neritic zone, is that the young Chaetognatha habitually have their centre of distribution nearer the surface than do the adult forms (See Russell 1931) and that during the night-time they rise to the upper layers where they remain for a longer period than do the adults. Consequently any surface drift of water towards the shore such as that caused by wind, transports many young, but relatively few adults to the in-shore waters.

Sagitta minima Grassi 1881.

This was the only species present in the Nornalup hauls. It was not taken at Cockburn Sound. *S. minima* occurs in the Atlantic, Pacific and Indian Oceans, approximately between 40 N. and 40 S. Usually referred to as an epi-planktonic or meso-planktonic form, this species is nevertheless common in in-shore hauls. The following table is prepared from the nine specimens taken. Only one specimen came into each of the highest and lowest classes, but as these are the class intervals which most authors have adopted for this species, it was thought desirable to retain them.

Length.	Tail (%).	Hooks.	Ant. Teeth.	Post Teeth.
7–9 mm.	17·5	7	5	10
5–7 mm.	17–19	6–8	3–4	4–6
3–5 mm.	20	7	3	4

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Sagitta enflata Grassi 1881.

This epiplanktonic form whose distribution is similar to that of *S. minima*, was represented by four individuals taken in a bottom haul (c. 10 m.) made in Cockburn Sound on July 22nd. Their measurements were very similar. All were immature.

Length.	Tail (%).	Hooks.	Ant. Teeth.	Post. Teeth.
7·8–9·3 mm.	16–21	9–10	5–6	6–7

Sagitta robusta Doncaster 1902.

This is a tropical to subtropical form, usually found between 30.N and 30.S. Fifteen specimens were taken, the species being represented in all the hauls made in Cockburn Sound.

Length.	Tail (%).	Hooks.	Ant. Teeth.	Post Teeth.
7–8 mm.	26	5–7	3–4	5–7
6–7 mm.	26	8	3	5
5–6 mm.	26–27	6–8	4–5	5–6
4–5 mm.	26	6–7	3–4	4–6
3–4 mm.	28–30	6–7	3	4–5

Sagitta bipunctata Quoy and Gaimard 1827.

This is another epiplanktonic form which has been recorded in the Atlantic, Pacific and Indian Oceans, between 40.N and 40.S. Six specimens were present in a haul made on May 14th, 1941. All were immature.

Length.	Tail (%).	Hooks.	Ant. Teeth.	Post. Teeth.
5–6 mm.	28	7–9	5–6	6–7
4–5 mm.	27–30	7–9	3–5	5
3–4 mm.	29	7	3	4

All four of the species recorded here are of cosmopolitan distribution. Undoubtedly further work on the plankton of Western Australian waters, particularly off-shore waters, will show that the numbers and species occurring here are as great as elsewhere.

REFERENCES.

Doncaster, L., 1902: Chaetognatha. *Fauna and Geography of the Maldive and Laccadive Archipelagoes*, Vol. I., pt. 2, pp. 209-218.

Grassi, B., 1881: Interno ai Chetognati. *Rend. Inst. Lombardo*, ser. (2), Vol. 14, pt. 6, pp. 193-213.

Johnston, T. H., & Taylor, B. B., 1919: Notes on the Australian Chaetognaths, *Proc. Roy. Soc., Queensland*, Vol. XXXI., pp. 28-41.

Quoy, J. R. C., & Gaimard, P., 1827: Observations zoologiques faites a bord de l'Astrolabe en Mai 1826 dans le detroit de Gibraltes, *Ann. Sci. Nat.*, Vol. X., pp. 5-239.

Ritter-Zahony, R. von., 1910: Chaetognathen, *Die Fauna Sudwest Australiens*, Bd. III., pp. 123-126.

Russell, F. S., 1931: Vertical Distribution of Marine Macroplankton X. Notes on the behaviour of *Sagitta* in the Plymouth area. *Journ. Mar. Biol. Assoc.*, Vol. XVII., pp. 391-414.

——————1936: Observations on the distribution of plankton animal indicators, made on Col. E. T. Peel's yacht "St. George" in the mouth of the English Channel. *Journ. Mar. Biol. Assoc.*, Vol. XX., pp. 507-522.

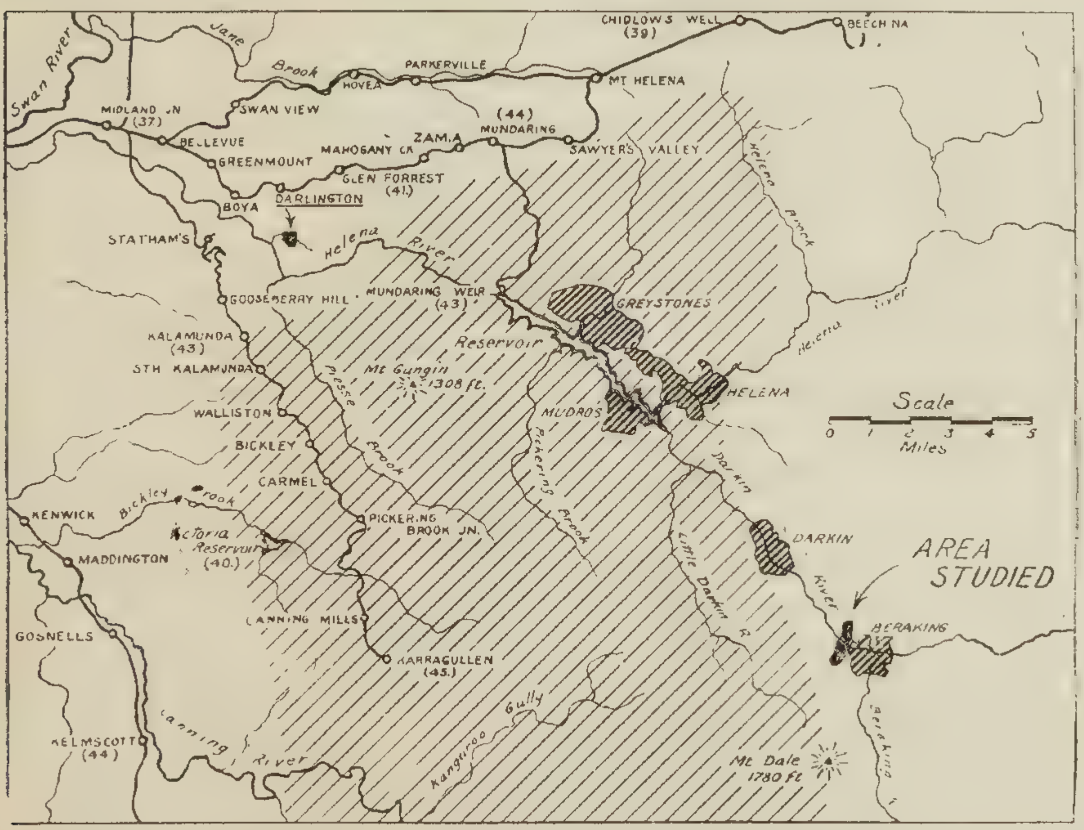
Tokioka, T., 1940: A small Collection of Chaetognaths from the Coast of New South Wales. *Rec. Australian Museum*, Vol. XX., No. 6, pp. 367-379.

3.—AN ECOLOGICAL STUDY NEAR BERAKING FOREST STATION.

By R. F. Williams, M.Sc.*

Communicated by Miss A. M. Baird, 14th November, 1944.

This paper records certain ecological field work conducted in 1932. Absence from the State has precluded the extension of this work, and a sense of its incompleteness made the author withhold it from publication. This decision is now reversed in the hope that the work may stimulate further interest in the ecology of the State. In the study of this subject Western Australia lags far behind the other States of the Commonwealth, and in certain areas the ravages of bushfires have so modified the vegetation that it is becoming increasingly difficult to define and classify the natural plant communities. Elsewhere, the rapid extension of land development may soon make it impossible to piece together a picture of the natural vegetation of the affected areas.



Text fig. 1.—Locality Plan. The light hatching shows the distribution of the "prime Jarrah forest," and the heavy hatching that of the pine plantations. The figures in parentheses indicate rainfall in inches per annum.

Beraking Forest Station is at the confluence of the Beraking and Darkin Rivers and is some thirteen miles south-east of the Mundaring Weir (*see* Text fig. 1). The area studied constitutes a broad transect across the Darkin River Valley and is immediately west of the Beraking pine plantation. Part of the area has since been cleared for further afforestation (*see* Text fig. 2, sections 14 and 15), and it would be of interest to study the growth response of the pines in relation to the vegetation types mapped for this portion of the area. The Beraking area is about seventeen miles from the small area

* From the Department of Botany, University of Western Australia.

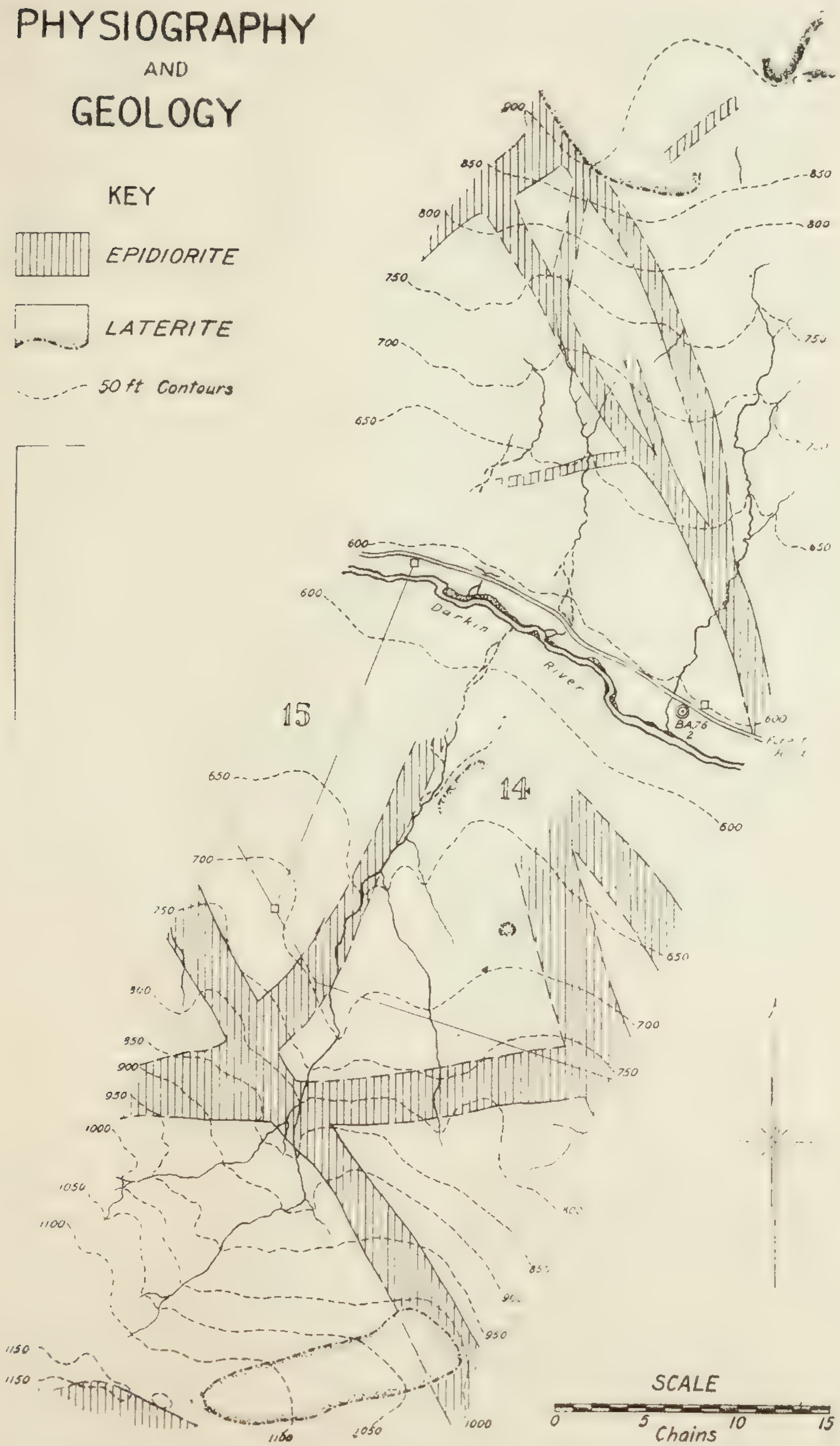
near Darlington studied previously (Williams, 1931–32), and between them lies a belt of the "prime Jarrah forest." Both areas fall within the semi-arid, warm-temperate bioclimatic zone as defined by Davidson (1936); thus for only five months, May to September inclusive, the ratio P/E is greater than 0·5. The mean annual temperature is between 60° and 65°F., and the mean annual rainfall is approximately 40 inches. The geology of the two areas is essentially the same, and as far as may be judged from a superficial examination of the soils, several of the soil types are represented in each of the localities. These common climatic and edaphic features add interest to a comparison of the vegetation of the Beraking and Darlington areas.

The area was first covered by a chain and compass survey, using the survey peg near reference tree BA. 76/2 as the datum, and the boundary pegs of section 14 as checks. The 50 ft. contours shown in Text fig. 2 are based on Abney level readings and an assumed altitude of 600 ft. for the datum peg. The mapping of geological features was based on outcropping rock and other surface indications; the more conjectural boundaries of epidiorite dykes are shown as broken lines. The plant communities of Text fig. 3 were determined solely by tree dominance. This criterion was chosen here, as at Darlington, because of the detailed nature of the work, and because the writer felt that it was premature to attempt the direct mapping of plant associations except on a basis of wide field experience. Information concerning the shrub stratum and ground flora was obtained from a series of 68 sampling sites, most of which are shown in Text fig. 3. For each site the component species were allocated to five somewhat arbitrary frequency-classes (dominant, abundant, frequent, occasional, and rare). The sampling sites were later grouped into larger units of from one to eight sites on a basis of obvious similarity of habitat and floristic composition; average frequency symbols of the more important plant species in such units are given in Table 1. Many other species, including herbaceous types, were recorded for these sites and for the seral communities not included in the analysis.

PHYSIOGRAPHY, GEOLOGY AND SOILS.

Although the Darkin valley west of Beraking is not so rugged and gorge-like as is the Helena valley near Darlington, it is by no means that of a mature stream. The upper slopes are steep and there are considerable areas of exposed rock and shallow soil. Even where the soils are sufficiently developed to carry an open sclerophyll forest, they are very variable in depth and include rock fragments and boulders in the upper horizons. Below the 700 ft. contour the slope is much reduced, the soils are more mature and, to the south of the river, there is a band of light sandy loam which is alluvial in character. The minor tributaries shown in Text fig. 2 are little more than gutters which flow only after heavy rain. Their courses are distinct at first but tend to be lost in the sandy soils below the 650 ft. contour. There is, however, a more or less permanent spring at the 850 ft. level of the stream on the southern slope; it occurs above the intersection of two epidiorite dykes.

The "breakaway" of the laterite level is at approximately 900 ft. on the northern side of the river, and the lateritic tableland which extends to the north of the area is almost flat. The gap shown in the "breakaway" is the outlet for an area over which the laterite has disintegrated to an extremely gravelly soil with no boulders. Near the southern boundary of the area there is an "island" of laterite which dips north-east at 10° and, at its highest point, is more than 200 feet above the tableland to the north. An extensive lateritic plateau lies to the west of this "island." Other small areas of laterite in the



Text fig. 2.—Physiography and Geology of the Beraking Area.

vicinity occur at varying altitudes and exhibit pronounced angles of dip. Lateritic gravel is not confined to the areas mentioned, but is present at least in the surface layers of much of the soil derived from granite. Two considerable areas of such gravelly soil occur between the 650 and 750 ft. contours of the southern slope, and at two points indicated in Text fig. 2 there are accumulations of lateritic boulders. Presumably both the gravel and the boulders are derived from the once continuous lateritic " cuirass," and are not remnants of a shelf of low-level laterite.

Several of the epidiorite dykes of the area strike in a north-northwesterly direction, but others cross these more or less at right angles. On the southern slope the relatively slow weathering of the dykes has influenced the topography to some extent. The red soils derived from these basic dykes do not contain lateritic gravel except in the vicinity of the " breakaways."

VEGETATION.

For the Darlington area Williams (1931–32) recognized and described two plant associations ; the *Eucalyptus calophylla-E. redunca* association on soils derived from granite and epidiorite, and the *Eucalyptus marginata* association normally developed on laterite and on soils containing lateritic gravel. Within the former association, consociations of *E. calophylla* and *E. redunca* were also distinguished. Had the area been extended to include the gorge of the Helena River, a third association dominated by *Eucalyptus rudis* would have been described for the more favourable habitat associated with permanent water.

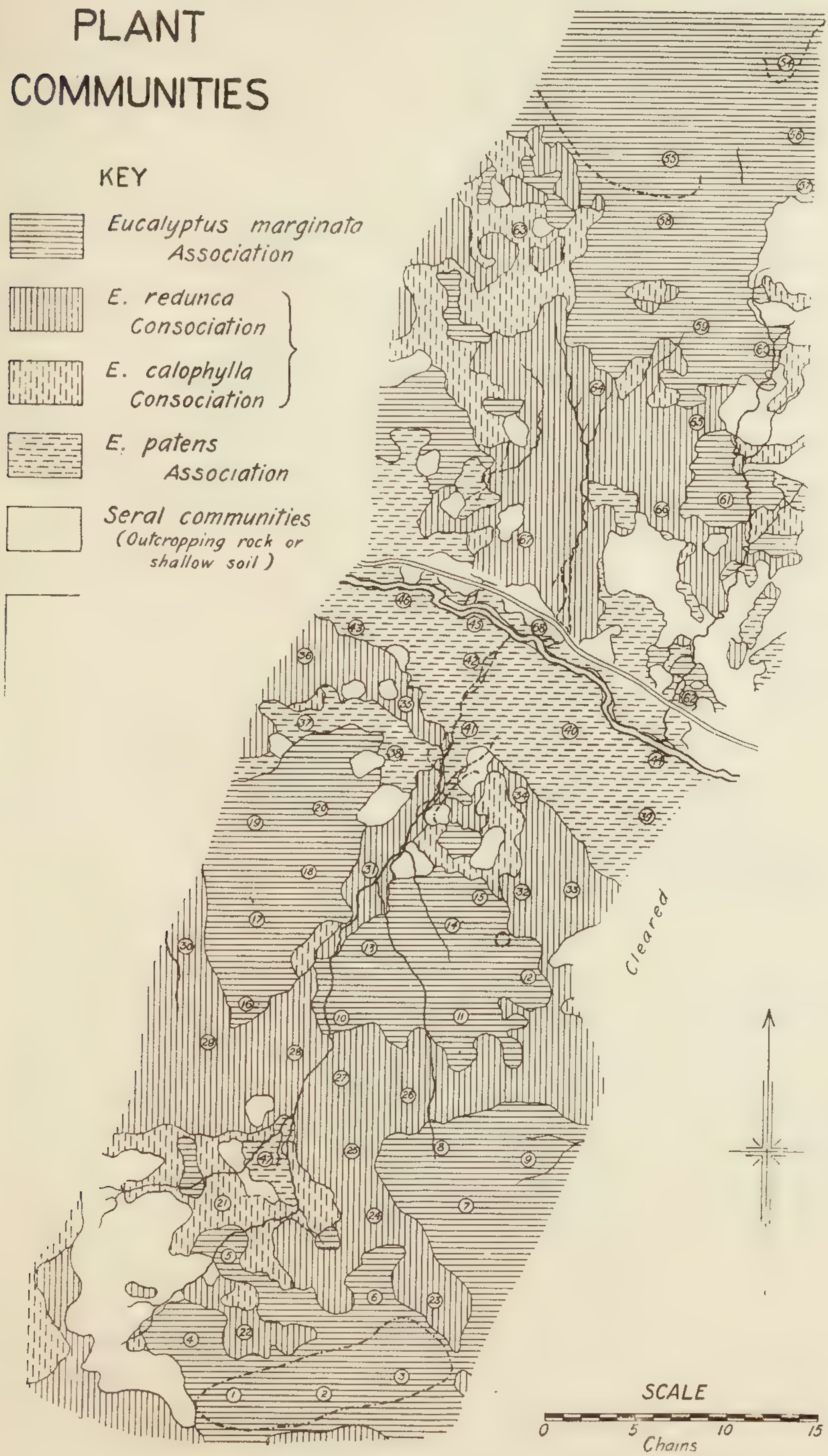
In naming the plant communities mapped in Text. fig. 3 of the present paper, the writer has retained the classification given above, but no considerable area of the *E. calophylla-E. redunca* association as distinct from its consociations was found. Small areas on which both eucalypts occur together have been mapped according to dominance. The community of which *Eucalyptus patens* is the tree dominant is certainly a distinct plant association. *Eucalyptus rudis* occurs only with *E. patens* on the area studied, but it dominates what is undoubtedly a distinct association on low-lying river flats in the vicinity. The plant communities of the Beraking area, together with their respective areas, were as follows :—

		acres.
1.	*E. marginata* association	70·0
2.	*E. redunca* consociation	53·3
3.	*E. calophylla* consociation	16·7
4.	*E. patens* association	22·8
5.	Seral communities	21·3
	Total	184·1 acres.

In the brief descriptions which follow, the figures in parentheses refer to the sampling sites of Text fig. 3 and Table 1.

Eucalyptus marginata Association (1–20, 48–62).

This association is developed in three fairly distinct forms on the Beraking area. These differ in structure and to some extent in their floristic composition. For the district as a whole, the most typical form is that found on the lateritic plateau (1–3, 48–55), where it tends to form a closed sclerophyll forest. This is almost a pure stand of *E. marginata* (five to six trees per square chain) on the tableland to the north of the area studied, but elsewhere



Text fig. 3.—Plant Communities of the Beraking Area.

NB.—Sampling sites 48-53 are on the tableland to the North of the area.

E. calophylla is present in small numbers. In places, *Banksia grandis* and *Casuarina Fraseriana* form an ill-defined stratum of small trees (cf. the *C. Fraseriana* society described for the Darlington area). *Xanthorrhoea Preissii* and *Macrozamia Reidlei* are constant members of the association and, by virtue of their height (3–6 ft.), must be excluded from the stratum of small shrubs and herbs. The latter is dominated by *Hibbertia hypericoides*, while *Hibbertia montana*, *Adenanthos barbigera*, *Hakea ruscifolia* and *Dryandra nivea* are important species of the stratum.

A second form of the association is to be found on steep gravelly slopes (4–9, 56–60), usually in direct contact with the lateritic plateau. On this habitat *E. marginata* is stunted, and there are many more trees per unit area ; *E. calophylla* and *E. redunca* may both be present, but *Banksia* and *Casuarina* are absent. Furthermore, the whole appearance of the association is altered by the increased frequency of *Xanthorrhoea Preissii* (Plate 1, fig. 2), many specimens of which have not developed the characteristic grass-tree habit. This latter feature brings the species into the shrub stratum, of which it may even be the dominant. Elsewhere *Hibbertia hypericoides* retains the dominance, though *Hakea bipinnatifida* may be a co-dominant. Other important members of the stratum are *Dryandra nivea*, *Gompholobium marginatum*, *Hakea amplexicaulis*, *Petrophila striata*, *Hibbertia montana*, *Scaevola striata* and *Xanthosia peltigera*.

The third form of the *E. marginata* association is to be found on the more mature gravelly soils of the lower slopes (10–20, 61–62). This habitat supports a stand which is as good as or even better than that on the lateritic plateau, but the associated trees are those which occur on the steep slopes. *E. patens* is only present in areas of transition. The shrub stratum is intermediate in density by comparison with the other two forms, but there is more evidence of modification by fire than elsewhere. *Hakea bipinnatifida* and *Hibbertia hypericoides* are locally dominant, and *Xanthorrhoea Preissii* is again prominent. Other important members of the shrub stratum are *Dryandra nivea*, *Hibbertia montana*, *Baeckea camphorosmae*, *Bossiaea ornata*, *Scaevola striata* and *Xanthosia peltigera*.

These three forms of the *E. marginata* association are illustrated in Plate 1, figs. 1, 2 and 3 respectively. The first of these is typical of the association above the laterite "breakaway" ; the apparent openness of the community is due to the fact that the observer is looking out over the valley through a narrow belt of trees. The marked differences in structure demonstrated by these photographs suggest that it might be better to give each form the status of an association, and to group them together as an *E. marginata* edaphic complex (*vide* Wood, 1939). If this were done it would still not be clear whether the first or the third form here described should be styled the edaphic climax association. The first is the more widespread type in the vicinity and it is more uniform in structure and floristic composition ; it occurs, nevertheless, on a habitat in which soil formation is distinctly inhibited by the laterite capping. The third form, though developed on a more mature soil type, is discontinuous in distribution and much more variable in structure and composition. For the present, therefore, it would seem wise to avoid any attempt to interpret these communities in terms of the concept of plant succession.

Eucalyptus calophylla—E. redunca Association.

It has been indicated that this association is not developed at Beraking in the same manner as at Darlington and, in the light of wider experience in the field, it may prove advisable to subdivide the community at Darlington into three distinct associations.

The association as a whole is best described as an open sclerophyll forest, and at Beraking the component eucalypts are segregated into more or less pure stands of one or the other. The *E. calophylla* consociation is poorly developed on the area studied, but the *E. redunca* consociation covers a considerable area and is represented by two distinct types. These, too, might well be described as separate associations within an edaphic complex.

Eucalyptus calophylla Consociation (21, 63).

This community is of less frequent occurrence at Beraking than it is at Darlington, though a fine stand of some 25 acres extent occurs to the north-west of the area studied. As at Darlington, the community tends to be restricted to granitic soils, possibly because of more favourable soil-moisture relations. The best example on the area studied is above the spring and below an extensive area of bare granite and shallow soil (21). *E. redunca* and *E. marginata* are associated eucalypts, though not in the immediate vicinity of the sampling site. *Xanthorrhoea Preissii* is abundant and *Macrozamia Reidlei* frequent in occurrence. *Hakea bipinnatifida* is the shrub dominant, while *Hibbertia hypericoides*, *Hakea undulata*, *Dryandra nivea*, *Acacia pulchella* and *Gompholobium marginatum* are important species of the stratum.

On the northern slope (63), the shrub stratum of this community is greatly modified by fire, as is shown by the local dominance of the fern, *Cheilanthes tenuifolia*, and the abundance of the annual composite, *Helipterum Cotula*. *Ranunculus lappaceus* is present, but the more typical sclerophyllous undershrubs are poorly represented.

Eucalyptus redunca Consociation (22–36, 64–67).

Comparison of Text figs. 2 and 3 reveals a strong correlation between the distribution of this plant community and the epidiorite dykes of the area. This is very pronounced on the southern slope, and it would be even more obvious if a map showing the distribution of the red soils derived from these basic rocks were available. The parallel observations on this point made by Clarke and Williams (1926–27) and Williams (1931–32) for the Darlington area are thus amply confirmed.

On the steep upper slopes where the soil is definitely immature (22–30, 64–66), the trees are somewhat stunted but have a relatively high frequency (*see* Plate 2, fig. 4); *E. calophylla* may be present, but *E. marginata* occurs only on transitional areas (*e.g.* 22–33). *Xanthorrhoea* and *Macrozamia* are prominent, and the shrub stratum is well developed and rich in species. Dominance of this stratum is shared by the two ubiquitous species *Hibbertia hypericoides* and *Hakea bipinnatifida*, with *Acacia pulchella* coming in less frequently as a local dominant. Other important species are *Hibbertia montana*, *Dryandra nivea*, *Hakea undulata*, *Petrophila striata*, *Lasiopetalum floribundum*, *Gompholobium marginatum*, *Phyllanthus calycinus*, *Eryngium rostratum*, *Scaevola striata* and *Stylidium reduplicatum*.

On the more mature soil of the lower slopes (31–36, 67), the community tends to become a pure stand of *E. redunca*; *E. calophylla* and *E. patens* may, however, be present on areas of transition. The trees are well developed and somewhat widely spaced (*see* Plate 2, fig. 5), but the shrub stratum is poorly developed and patches of bare soil are not infrequent. *Xanthorrhoea* and *Macrozamia* are much less frequent and may sometimes be absent. Dominance of the shrub stratum is assumed by no fewer than four species at different places within this vegetation type: the species concerned are *Hibbertia hypericoides*, *Hypocalymma angustifolium*, *Dryandra nivea* and *Dampiera alata*.

This feature may or may not be attributable to the influence of bushfires. Other species of importance are *Hibbertia montana*, *Hibbertia gracilipes*, *Hakea bipinnatifida*, *Grevillea pilulifera*, *Baeckea camphorosmae*, *Eryngium rostratum* and *Helipterum Cotula*.

Eucalyptus patens Association (37–47, 68).

Apart from transitional areas which grade into the *E. redunca* consociation, the *E. patens* association is restricted to the alluvial soils of the area studied, and hence to the southern bank of the river. Even here the association exhibits an ill-defined zonation, presumably dependent upon such factors as depth of soil and permanence of water.

On the transitional areas (37–38, 68), *E. calophylla* is common as an associated tree species, but *E. redunca* and *E. marginata* may also be present. *Acacia saligna* and *Dryandra nivea* are the shrub dominants for the sampling sites to the north and south of the river respectively. In other respects the shrub stratum has closer affinities with that of the low-level *E. redunca* community than with the shrub stratum of the typical *E. patens* association. *E. redunca* does not penetrate the outer zone of the *E. patens* association (39–43, and Plate II, fig. 6), except along the line of the creek (41–42), where it may be associated with the epidiorite dyke which presumably extends beneath the alluvium (*see* Text fig. 2). Elsewhere *E. calophylla* and *E. rudis* are associated tree species. *Xanthorrhoea Preissii* is abundant and the individuals are usually well developed, but *Macrozamia Reidlei* is absent from both outer and inner zones. In different places, *Acacia saligna* and *Hypocalymma angustifolium* are shrub dominants, but the following are also important :—*Pimelea argentea*, *Dryandra praemorsa*, *Acacia extensa*, *Hibbertia gracilipes*, *Dampiera linearis* and *Scaevola striata*.

The frequency of *E. rudis* increases for the inner zone of the association (44–46) ; *Banksia verticillata* is prominent as a small tree, and *Melaleuca rhaphiophylla* is also present. *Xanthorrhoea* is quite infrequent in occurrence. *Trymalium spathulatum* and *Acacia extensa* share the dominance of the shrub stratum, but *Acacia saligna* and *Agonis linearifolia* are important constituents, and *Viminaria denudata* and *Dryandra praemorsa* are worthy of note.

The one remaining example of the *E. patens* association is that in the vicinity of the spring on the southern slope (47). This isolated sample is some 250 feet above the rest of the association, and its habitat may differ with respect to soil and water relations. Whatever the cause, this example of the community differs markedly in floristic composition, and two of its constituent species have not been observed by the writer elsewhere in the Darkin or Helena River valleys. *E. calophylla* and to a lesser extent *E. marginata* are associated trees, and *Persoonia longifolia*† is present as a small tree. *Macrozamia* and *Xanthorrhoea* both occur but are not common. *Acacia extensa* dominates the shrub stratum, but the following species are conspicuous :—*Agonis linearifolia*, *Viminaria denudata*, *Hibbertia* sp., *Lepidosperma tetraquetrum*† and *Dryandra praemorsa*.

SUMMARY AND CONCLUSIONS.

The sclerophyll forest communities occurring on a small but representative area near Beraking Forest Station, Western Australia, have been mapped and described in some detail. For the sake of conformity with earlier work, these communities are tentatively classified within three major units, namely :—

† These species were not observed elsewhere.

the *Eucalyptus marginata* association, the *E. calophylla-E. redunca* association, and the *E. patens* association. It is considered, however, that these units are too heterogeneous to be styled plant associations, and evidence is adduced which suggests that they might be more accurately described as edaphic complexes ; in which case seven or eight plant associations would have to be distinguished for the Beraking area.

The distribution of the plant communities may be determined by edaphic factors such as the distribution of laterite and lateritic detritus, the soil type as determined by the underlying rock formations, the maturity of these soils, and the soil-water relations. A more detailed study of these factors would be desirable in all future ecological investigations of this nature, but was not possible at the time of this investigation.

ACKNOWLEDGMENTS.

The writer is indebted to the Forests Department for providing accommodation and other facilities in the field, and to Miss Nancy T. Burbidge for constructive criticism of the manuscript. The completion of the field work in 1934, when the writer made a brief return visit to the State and to Beraking, took place during the tenure of a Hackett Research Studentship of the University of Western Australia.

REFERENCES.

Clarke, E. de C. and Williams, F. A., 1926–27—" The Geology and Physiography of Parts of the Darling Range, near Perth," *Journ. Roy. Soc. West. Aust.*, Vol. XII, pp. 161–178.

Davidson, J., 1936—" Climate in Relation to Insect Ecology in Australia. 3. Bioclimatic Zones in Australia," *Trans. Roy. Soc. South Aust.*, Vol. 60, pp. 88–92.

Williams, R. F., 1931–32—" An Ecological Analysis of the Plant Communities of the ' Jarrah ' Region occurring on a Small Area near Darlington," *Journ. Roy. Soc. West. Aust.*, Vol. XVIII., pp. 105–124.

Wood, J. G., 1939—" Ecological Concepts and Nomenclature," *Trans. Roy. Soc. South Aust.*, Vol. 63, pp. 215–223.

PLATE 1.

Fig. 1.—*E. marginata* association on laterite near sampling site 3.

Fig. 2.—*E. marginata* association on steep gravelly slope below the laterite "breakaway" and near sampling site 7.

Fig. 3.—*E. marginata* association on more mature gravelly soil near sampling site 17.

Fig. [illegible] *E. redunca* consociation on steep slope and immature soil type near sampling site 27.

Fig. [illegible] *E. redunca* [illegible] soil type near [illegible]

Fig. [illegible] alluvial soil near [illegible] approximately [illegible]

Table 1.—Frequency Table for the important Plant Species of the Area.

General Location.	South of River.															North of River.							
Sampling Sites (*See* Text fig. 3).	1-3.	4-6.	7-9.	10-15.	16-20.	21.	22-25.	26-30.	31.	32-34.	35-36.	37-38.	39-43.	44-46.	47.	48-5[illegible].	[illegible].	59-60.	61-62.	63.	64-66.	[illegible].	6[illegible].
TREES—																							
Eucalyptus marginata, Sm.	*d*	*d*	*d*	*d*	*d*		o					o			o	*d*	*d*	*d*	*d*				
Eucalyptus calophylla, R.Br.	o	o	o	o	o	*d*	o	o		o		f	o		f	o	o	o	f		o		
Eucalyptus redunca, Schau. v. *elata*, Benth.		o	o	o	o		*d*	*d*	*d*	*d*	*d*	o	o					o	o	o	[illegible]	[illegible]	
Eucalyptus patens, Benth.									o	o		*d*	*d*	*d*	*d*				o				[illegible]
Eucalyptus rudis, Endl.													o	f									
SMALL TREES—																							
Banksia grandis, Willd.	o															o							
Banksia verticillata, R.Br.														f									
Casuarina Fraseriana, Miq.	f																						
Melaleuca rhaphiophylla, Schau.														o									
Persoonia longifolia, R.Br.															f								
SHRUB STRATUM AND GROUND FLORA—																							
Macrozamia Reidlei, (Gaud.) Gardner	f	f	f	f	f	f	f	f	f	o	o	o			o	f	o	o	f	f	f	f	
Xanthorrhoea Preissii, Endl.	f	f	a	a	f	a	a	f	f	f	f	f	a	o	o	f	f	f	a	a	f		
Acacia extensa, Lindl.													f	*cd*	*d*								
Acacia pulchella, R.Br.				o		f	o	*ld*										o					
Acacia saligna, Wendl.													*ld*	f									
Adenanthos barbigera, Lindl.	a																						
Agonis linearifolia, (D.C.) Schau.														f	a								
Baeckea camphorosmae, Endl.				la					f														
Bossiaea ornata, (Lindl.) Benth.	o	o	o	o	f		o	o				o											
Cheilanthes tenuifolia, (Burm.) Swartz																				*d*			
Dampiera alata, Lindl.													o										
Dampiera linearis, R.Br.		o	o	o	o		o	o		o	f	o	f	o					f		o	o	
Dryandra nivea, R.Br.	o	f	f	f	f	f	f	f	f	*ld*	o	*d*	o			f	o	f	a		a		
Dryandra praemorsa, Meissn.		o						o					f	o	f							o	
Eryngium rostratum, Cav.							o						o	o							[illegible]		
Gompholobium marginatum, R.Br.		f	f	f	o	f	f	f	f		f	o							o				f
Grevillea pilulifera, (Lindl.) Gardner		o	o	o	o	o	o	o	o	f	f	o											
Grevillea synapheae, R.Br.	o	o			o		o					o											
Hakea amplexicaulis, R.Br.			a				o																
Hakea bipinnatifida, R.Br.	o	a	*cd*	*d*	f	*d*	a	*cd*	a	o		o	o		o	o	a	a	*d*	o	*d*	o	f
Hakea ruscifolia, Labill.																la							
Hakea undulata, R.Br.		o		o		f	o	o					o		o								
Helipterum Cotula, (Benth.) D.C.										o			o					o		a	f	a	o
Hibbertia gracilipes, Benth.				o						o	o	o	a	o					o		o		
Hibbertia hypericoides, (D.C.) Benth.	*d*	*d*	*cd*	a	*d*	a	*d*	*cd*	*d*	*ld*		o				*d*	*d*	*d*	f		la		
Hibbertia montana, Steud.	f	o	f	f	o		o	f	f	o	a	f	o			f	o	o	f		a	f	a
Hibbertia sp.													o		a								
Hypocalymma angustifolium, Endl.								o			*d*		*ld*						f		o		f
Lasiopetalum floribundum, Benth.		o						la															
Lepidosperma tetraquetrum, Nees.															la								
Leptomeria Cunninghamii, Miq.								o								o	o	o	o				
Leucopogon capitellatus, D.C.				o	o											o	o		o				
Petrophila striata, R.Br.	o	f	o		o		o	o								o							
Phyllanthus calcycinus, Labill.				o			o	o	o				o				o		o				
Pimelea argentea, R.Br.													la										a
Ranunculus lappaceus, Sm.													o							f	o		
Scaevola striata, R.Br.	o	o	f	f	o					o	o	a	f			o	o	f	f		f	o	
Stylidium amoenum, R.Br.	o	o	o		o		o	o								o	o						
Stylidium Brunonianum, Benth.		o	o		o		o	o				o											
Stylidium reduplicatum, R.Br.							o	f							o								
Trymalium spathulatum, (Labill.) Ostf.													o	*cd*									
Viminaria denudata, Sm.														o	a								
Xanthosia peltigera, (Hook.) Benth.	o	o		o	o											o	f						

N.B.—Sampling sites 48–53 are on the lateritic tableland to the north of the area studied, and are not shown in Figure 3.

d—dominant, *cd*—co-dominant, a—abundant, f—frequent, o—occasional.

4—THE ESSENTIAL OILS OF THE WESTERN AUSTRALIAN EUCALYPTS.

Part VIII.

THE OILS OF *EUCALYPTUS CAMPASPE* S. MOORE AND *E. KOCHII* MAIDEN ET BLAKELY.

By E. M. Watson, Ph.D., F.A.C.I.

With a Note on *E. campaspe*.

By C. A. Gardner.

Read: 10th April, 1945.

Eucalyptus campaspe.

The oil of *E. campaspe,* distilled from material collected at Widgiemooltha in October, 1922, has been described by Phillips (1). It was shown to consist largely of hydrocarbons, having a low solubility in alcohol, although esters and alcohols made up more than 20 per cent. of the oil and the aldehyde content was estimated at 8 per cent. The cineole content of the oil was given as about 15 per cent.

The oil described in the present paper was distilled from leaves collected in April, 1942, about a mile north of the Lloyd George Mine at Gibraltar, that is, about 12 miles roughly south-west of Coolgardie. The branchlets were taken from a tree about 25 feet high, growing in heavy red loam on a flat between two auriferous ridges. It was collected by Mr. G. E. Brockway and its identity was verified by Mr. C. A. Gardner. The distillation was complete in 3 to 4 hours and the yield was a little over 1.2 per cent. by weight calculated on thoroughly air dried material. The oil was yellow in colour and had a somewhat irritant though camphoraceous odour. A comparison of the more important physical and chemical properties of this oil with those of the oil distilled by Phillips shows that the two differ markedly from one another. The most notable differences lie in the very much higher cineole content (which accounts for the higher solubility in alcohol, the higher specific gravity and lower refractive index) and in the lower aldehyde, alcohol and ester content of the present oil.

	Phillips.	Watson.
Yield	0·72%	1·22%
Specific Gravity at 15°C.	0·9118	0·9225
Refractive Index at 20°C.	1·4762	1·465
Optical Rotation	+ 5·43°	+ 7·15°
Solubility in 80 per cent. alcohol	In 5 volumes	In 1 volume
Saponification Value (cold)	....	1·1
Saponification Value (hot)	8·4	3·5
Alcohols calculated as $C_{10}H_{18}O$	18·65%	9·4%
Aldehydes	8% (a)	1·8% (b)
Cineole	15% (c)	64% (d)

(a) By absorption ; (b) by hydroxylamine, calculated as $C_{10}H_{14}O$; (c) by phosphoric acid ; (d) by *o*–cresol.

The oil was soluble in 10 volumes of 70 per cent. alcohol, had an acid value of 0.3 and contained 7.2 per cent. of geraniol. It gave the usual colour reactions for aromadendrene. The cold saponification value corresponds to nearly 0.4 per cent. of geranyl acetate, while the hot value corresponds to a little over 1.2 per cent. of total esters calculated as $C_{12}H_{20}O_2$.

11059/9/47.—380.

NOTE ON *EUCALYPTUS CAMPASPE.*

The disparity in the oil produced from specimens received from Widgiemooltha and Coolgardie may perhaps be explained by the difference between what appear to be two distinct forms of this species. Until ripe fruits have been obtained from Coolgardie we are not in a position to decide the true status of this form, and the position is rendered still more difficult by the fact that the type specimen is without fruits. The type was collected by Spencer Moore at Gibraltar in October, 1895, and was described by him in 1898 (2).

The species is represented in the Perth Herbarium by two sheets from Widgiemooltha, bearing buds, flowers and fruits (Gardner 1015 and 1043) and a single sheet from Montana Hill, Coolgardie (Gardner *sine no.*), with buds, flowers and immature fruits. The ripe fruits from Widgiemooltha show conspicuously exserted broadly deltoid valves, while unripe fruits from both localities, in which the capsule is undeveloped, exhibit a prominent calycine rim produced above the level of the ovary. I have not examined the type specimen at the British Museum (Natural History) but Maiden has illustrated the buds, together with specimens obtained at Coolgardie (L. C. Webster) and Fraser's Range (Helms) (3). The differences here are well marked between Webster's and Helm's specimens. In the absence of fruits from the type, it is not possible to make full comparisons, but, in the type specimen and in the specimens from Widgiemooltha and Fraser's Range, the operculum is longer than the calyx-tube, while in the Coolgardie specimens it is shorter and both the buds and the immature fruits are much larger. The differences are as shown hereunder.

	Coolgardie specimen.	Gibraltar (Type).	Widgiemooltha specimens.
Peduncle	10 mm. long, up to 5 mm. broad	6-8 mm. long, 3-4 mm. broad	6-9 mm long, 4-5 mm. broad
Buds	Broadly obovoid	....	ovoid to narrow-ovoid
Calyx-tube	4-5 mm. long, 7-8 mm. broad	4 mm. long, 6 mm. broad	3-4 mm. long, 5 mm. broad
Operculum	4 mm. long	6 mm. long	5-6 mm. long
Unripe fruits in similar stages	10 mm. diameter	....	5 mm. diameter

The Coolgardie specimens have more pruinose branchlets and more glaucous leaves than those of the Widgiemooltha specimens. The principal differences, however, are in the shape of the buds and the size of the fruits. The type would appear, from its description, to be closer to the Widgiemooltha and Fraser's Range forms than to the form obtained from Coolgardie.

C.A.G.

Eucalyptus Kochii.

This species was established by Maiden and Blakely from specimens collected near No. 2 Rabbit Proof Fence, some 50 or 60 miles east of Watheroo. The material used in this investigation represents the only other recorded ocurrence of the species and it was obtained about 8 miles east of Canna, more than 100 miles roughly north-west of its previous location.

It was collected at the end of November, 1944, by members of the Drug Panel of the Department of Industrial Development, and its identity was determined by Mr. C. A. Gardner. Further samples were collected from the same mallees two months later, when the mature plants were flowering and fruiting. Three specimens of oil were distilled, one from branchlets of both young and mature mallees, the latter in bud, collected in November; a second from the same young mallees alone and a third from the mature mallees bearing buds, flowers and fruits. The last two were collected in January, 1945.

The oil distilled rapidly and distillation was complete in about 3 hours. The yield varied from 2.1 per cent. by weight from undried leaves and branchlets to almost 3.9 per cent. from nearly dry material. The oil varied in colour from pale yellow to yellow and its odour was faintly irritant. The three specimens consisted very largely of cineole, the proportion ranging from 85 to 92 per cent. and the crude samples themselves conformed to the requirements of the British Pharmacopoeia for eucalyptus oil. The growth of the young mallees is luxurious and appears to be vigorous and, although the distribution of the species is not known at present, it seems evident that it could be closely cultivated on the outer fringe of the wheat belt.

The main physical properties and the cineole contents of the samples examined are as follow:—

Sample.	Specific Gravity.	Refractive Index.	Optical Rotation.	Solubility in 70% Alcohol.	Cineole Content.
1.	0·922	1·460	+1·9°	In 2·0 vols.	87·5%
2.	0·921	1·460	+3·8°	In 2·1 vols.	85·0%
3.	0·925	1·4595	+0·54°	In 1·8 vols.	92·0%

Sample 1 from mature mallees in bud and young mallees, collected 30th November, 1944.

Sample 2 from young mallees, collected 27th January, 1945.

Sample 3 from mature mallees bearing buds, flowers and fruits, collected 27th January, 1945.

The differences between these samples are such as would be expected from the lower cineole content and probably a slightly higher terpene content of samples 1 and 2. Sample 1 had an acid value of 0.7, cold and hot saponification values of 1.1 and 2.4 respectively and contained 0.023 millimole of aldehyde per gram, equivalent to 0.35 per cent. of aldehydes calculated as $C_{10}H_{14}O$. It gave no test for phellandrene.

The author is indebted to Mr. C. A. Gardner and Mr. G. E. Brockway for their assistance in this work.

REFERENCES.

(1) Phillips, 1922-23, *Journ. Roy. Soc. W. Aust.* Vol. IX., p. 107.

(2) Moore, 1898, *Journ. Linn. Soc. Lond.* (Botany), 34, p. 193.

(3) Maiden, Critical Revision of the Genus *Eucalyptus*, ii, plate 71.

5.—NOTES ON THE DISTRIBUTION IN SOUTH WESTERN AUSTRALIA OF *ECHIDNOPHAGA MYRMECOBII* ROTHSCHILD.

By C. F. H. JENKINS, M.A.

Read: 8th May, 1945.

The "stickfast" flea, *Echidnophaga myrmecobii,* is a native species which was originally described from various Western Australian mammals. With the disappearance of many of these mammals from their former haunts, however, and the spread of the rabbit, the latter has become the principle host of this flea in the South-Western portion of the State.

The following observations were commenced in June, 1940, when an attempt was made to determine the types of fleas carried by rabbits, the distribution of the fleas, the degree of infestation, and the seasonal fluctuations of the parasites.† It was not possible, with the time and facilities available, to carry out the investigations with sufficient detail to provide full statistical data to support the observations made, but it was felt that the particulars obtained were of sufficient interest to warrant the publication of these notes, which may serve as a useful foundation for any later work carried out on similar lines.

The various trips were made by car and rabbits were shot wherever possible and examined for fleas. Most of the rabbits were obtained at places adjacent to the road, but the numbers shot at the various localities were generally sufficient to establish whether fleas were present or not. Additional evidence was sought by inspecting trappers' catches, both in the field and in district freezing works. Details of these inspections have not been included in the table, but in all cases, they served to support the evidence gained from shooting in the surrounding neighbourhood. The three main survey trips were made in August and October, 1940, and in February, 1941, but many other subsequent records have been obtained, and the entire results are presented in the accompanying table.

Early in *August,* 1940, collections were made in various wheat belt districts, including Mandiga, Goomalling, Narrogin, and Katanning. Rabbits were examined in the freezing works at Northam, Katanning, and Narrogin. Infested rabbits were noted at Mandiga, Wongamine, South Goomalling, and the Northam Ice Works. Infestation was light in all cases.

In mid-August, the route being from Perth eastward to Merredin and northward to Northampton, parasitised rabbits were taken at the following localities:—Jennacubbine, Goomalling, Wyalkatchem, Yelbeni, Mandiga, Kulja, Irwin, Dongara, Geraldton, Carnamah. In general, rabbits were lightly infested, and in several instances only one or two fleas were found. A record of heavy infestation however, was obtained at Booralaming, and a further one at Carnamah. Evidence was obtained of clean and infested rabbits living in neighbouring colonies. Severe drought conditions were prevailing at the time, and the reduced rabbit population may not have been

† The purpose of this survey was to determine whether fleas were sufficiently numerous and widespread to serve as vectors of the rabbit virus (*Myxomatosis cuniculi*) and so assist in wholesale rabbit destruction. The first main trip was made in company with Mr. M. W. Mules an officer of the Animal Health Division of the Council for Scientific and Industrial Research and intimately associated with the Commonwealth's *Myxomatosis* research programme.

10772/8/47—380

favourable for the optimum development of ectoparasites. The next observations were made at the end of August, 1940, when some 20 or 30 rabbits were examined in the Lake Grace district without any trace of flea parasites being noticed. On the return journey, two lightly infested rabbits were obtained, one at Corrigin and the other at Quairading.

TABLE I.

Locality.	Date.	Number of Rabbits Examined.	Number of Infested.	Degree of Infestation.
Benecubbin	14–10–40	3	3	light*
Do.	6–5–43	2	0	
Do.	28–8–43	5	0	
Beverley	7–10–43	4	0	
Do.	24–11–43	3	0	
Booralaming	1940	1	1	heavy
Bowes	17–8–40	13	0	
Do.	2–3–41	4	0	
Bridgetown	24–9–41	5	0	
Do.	7–2–42	5	0	
Do.	11–12–42	7	0	
Capel	15–12–41	4	0	
Carnamah	20–8–40	11	1	heavy
Do.	17–10–40	3	0	
Do.	3–3–41	9	1	light
Chittering	21–8–40	6	0	
Do.	5–3–41	5	0	
Do.	23–9–41	2	0	
Coorow	21–8–40	5	0	
Corrigin (10 miles east)	29–8–40	1	1	light
Dalwallinu (10 miles west)	15–8–40	2	0	
Do.	15–10–40	2	0	
Do.	26–2–41	5	5	light
Dongara	16–8–40	2	2	light
Frankland River	4–1–41	5	0	
Gabbin	26–2–41	1	1	moderate
Geraldton (10 miles east)	17–8–40	11	1	light
Goomalling	13–8–40	4	4	light
Do.	24–2–41	5	5	heavy
Grass Valley	11–10–40	1	1	light
Do.	11–11–42	2	0	
Do.	5–11–43	5	0	
Do.	24–11–43	2	0	
Irwin	16–8–40	1	1	light
Isseka	2–3–41	9	0	
Do.	14–9–42	4	0	
Jennacubbine	13–8–40	1	1	light
Katanning	22–7–40	5	0	
Kukerin	27–8–40	2	0	
Kulja	15–8–40	1	1	light
Kununoppin	13–10–40	5	5	light
Lake Grace	28–8–40	27	0	
Manjimup (Bubarrup)	5–1–41	15	0	
Mingenew	19–8–40	6	0	
Do.	17–10–40	4	0	
Do.	19–5–41	1	1	light
Moora	17–10–40	4	0	
Do.	4–3–41	3	0	
Mandiga	14–8–40	7	7	light
Mt. Barker	3–1–41	1	0	

*Two or three fleas only.

Locality.	Date.	Number of Rabbits Examined.	Number of Infested.	Degree of Infestation.
Mukinbudin	5–5–43	3	0	
Mummballup	3–2–41	25	0	
Do.	11–2–42	22	0	
Nangeenan	12–10–40	13	12	light
Do.	3–5–43	20	1	light
Nansen	17–8–40	9	0	
Do.	14–9–42	6	0	
Newcarlbean	14–10–40	1	1	heavy
New Norcia	17–10–40	5	0	
Northamption	2–3–41	3	0	
Nungarin	13–10–40	1	1	light
Quairading (15 miles S.W.) ...	29–8–40	1	1	light
Roelands	2–11–40	4	0	
Toodyay	2–7–40	10	0	
Trayning	25–2–41	1	1	heavy
Seabrook	12–8–40	3	0	
Do.	9–10–40	4	0	
Do.	27–12–40	5	0	
Do.	8–11–43	3	0	
Do.	5–11–43	5	0	
Wagin	9–4–42	1	1	light
Wundowie	28–10–43	1	0	
Wyalkatchem	14–8–40	7	5	light
Yelbeni	14–8–40	4	4	light

In *October*, 1940, a hurried survey was made of many of the eastern and north-eastern and northern wheat belt districts visited in August. Rabbits were collected at Grass Valley, Nangeenan, Nungarin, Kununoppin, and Newcarlbean, and almost every animal examined was lightly or moderately infested. Further rabbits were shot at Mingenew, Dalwallinu, Carnamah, Moora, New Norcia, Bindoon and Chittering, but no fleas were discovered.

In late *November*, rabbits in the vicinity of Roelands were examined but carried no flea parasites.

In *January*, 1941, an examination was made of numerous rabbits in the lower South-West from Mount Barker, Muir's Bridge, Manjimup and Mummballup, but no fleas were collected.

In late *February*, 1941, the area covered in the late August of 1940 was again worked. Infested rabbits were collected at the main centres visited in August—Goomalling, Trayning, Gabbin, 10 miles west of Dalwallinu, and Dongara. The information obtained on the February trip showed the flea to have essentially the same distribution as in August, but there are several points of interest to note. Several rabbits shot near Dalwallinu were all slightly infested, whereas animals shot at this spot in August were clean. Again, in spite of a heavy infestation of rabbits at the spot sampled near Carnamah, only one infested rabbit was collected out of a number shot, giving comparable results to those obtained in August. Rabbits were shot on the return journey as in August, at Coorow, Moora, New Norcia, and Chittering,

but no fleas were seen. Some of the rabbits collected from Dongara and Greenough carried *E. gallinacea,* and these were the only localities from which this species was recorded during the census. Although the distribution of the flea proved to be generally similar in August, October and February, the October infestation appeared to be slightly more severe than the August one, and the February data showed a definite increase on that of the winter and spring months.

From a study of the accompanying map, it will be seen that the main flea infested areas are the Eastern and North-Eastern farming districts. The North coastal area, with the exception of one record East of Geraldton, and several records in August near Dongara, appears to be clean. The fact that none of the rabbits examined in the lower South-West and directly North of Perth carried fleas, indicates that the flea population in this region must be very low. Although no strict correlation between climate or soil type can be indicated, it would appear that the lighter rainfall areas of the State are the most favourable to the flea and that in this area, the light soil types are conducive to the most severe infestations.

That the flea population fluctuates violently, even in those areas which may be regarded as the most favourable, is indicated by the remarkably low counts recorded in 1943. No ready explanation is offering. It could not be due to a drop in the rabbit population, as actually an increase was evident. The good rainfall experienced in many districts may have had some significance, especially bearing in mind the absence of the flea from the better rainfall areas of the State. But much more research will be necessary before any satisfactory explanation can be presented as to the reason for the variable distribution and population indicated in the foregoing paper.

LITERATURE.

Bull, L. B. & Mules, M. W. 1944—An Investigation of *Myxomatosis cuniculi* with Special Reference to the Possible Use of the Disease to Control Rabbit Populations in Australia. *Journ. C.S.I.R.,* Vol. 17, No. 2, p. 79.

Mules, M. W., 1940—Notes on the Life History and Artificial Breeding of the Australian "Stickfast" Flea, *Echidnophaga myrmecobii* Rothschild. *Aust. Journ. Exp. Biol. and Med. Sci.,* Vol. XVIII., p. 385.

Rothschild, N. C., 1909—*Novitates zoologicæ,* Vol. XVI., No. 1, p. 57.

Rothschild, N.C., 1910—"A Synopsis of the Fleas Found on *Mus norwegicus decumanus. Mus rattus alexandrinus* and *Mus musculus.*" *Bul. Ent. Res.,* Vol. I, p. 89.

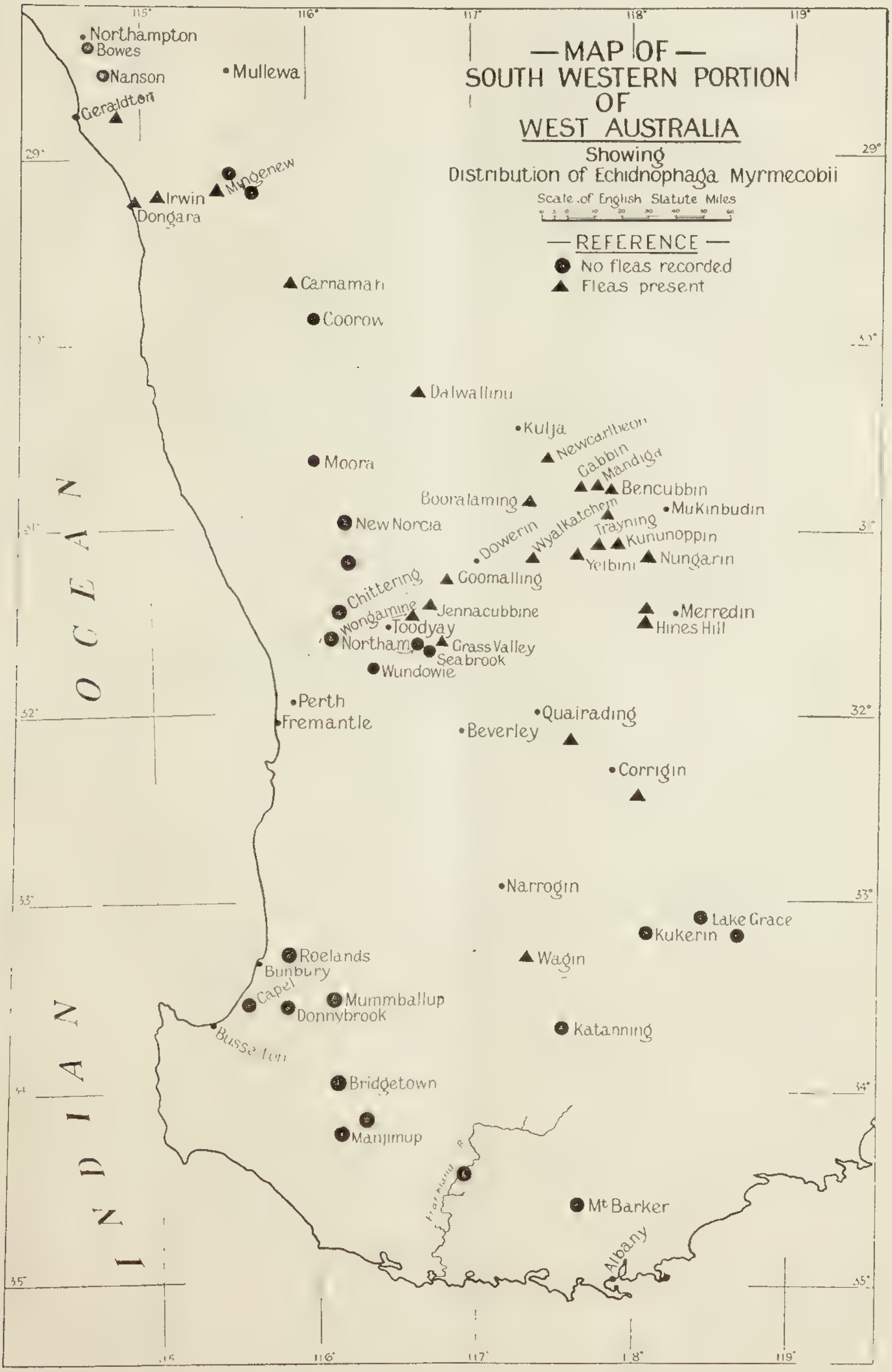


Fig. 1. Map showing distribution of *Echidnophaga myrmecobii.*

IGNEOUS ACTIVITY, METAMORPHISM, AND ORE-FORMATION IN WESTERN AUSTRALIA.

PRESIDENTIAL ADDRESS, 1945.

By REX T. PRIDER, Ph.D., B.Sc., F.G.S.

Delivered July, 1945.

CONTENTS.

1. INTRODUCTION.

The greater part of Western Australia is made up of Pre-Cambrian igneous rocks or rocks of metamorphic origin whose metamorphic characteristics have resulted in great part from igneous activity and associated earth movements. Moreover these rocks are both the home and source of the majority of our metallic mineral deposits. I feel therefore, in spite of the fact that the Pre-Cambrian geology of the State has been the subject of two previous Presidential Addresses to this Society (12, 39), that the volcanic history of the State has been the subject of one such address (59) and that one address has been given concerning metallogenetic epochs in Western Australia (87), that there is some justification for further consideration of the igneous record as seen in Western Australia and for an attempt to correlate this activity with metamorphism and ore formation. At the same time I feel that I owe an apology to one of our earliest Presidents, Mr. A. Gibb Maitland, if the title of my address is somewhat similar to that of his Presidential Address "The Volcanic History of Western Australia" (59), delivered to this Society some 18 years ago—in this period there has been some re-orientation of our views concerning Western Australian geology concomitant upon an increased knowledge of the distribution and relations of the rocks and of general petrogenetic principles and I should like to place before you this evening a summary, as I see it, of the present state of our knowledge concerning igneous activity and metamorphism in Western Australia

In dealing with such a wide area the work of many geologists must be taken into consideration—much of this work appears in published form in the various reports and bulletins issued from the Geological Survey Department but some is the result of research, both published and unpublished, by other workers—to all whose work I have utilised in compiling this summary, I express my thanks, but I should point out that the interpretation of the data used is mine and so I am solely responsible for any inaccuracies of interpretation.

Igneous activity implies the extrusion of molten rock materials (magmas) or their products at the Earth's surface (as in volcanic eruptions) or the intrusion of such magmas into the rocks of the outer crust of the Earth. Directly associated with igneous activity we have the production of metamorphic rocks (from pre-existing rocks affected by the hot intrusives and the earth-movements accompanying their emplacement) and ore deposits, which, in the case of primary deposits, are derived from rock magmas, generally during their final phases of consolidation. Such igneous activity was the dominant feature in this part of the world in Pre-Cambrian times, since when Western Australia has had a very quiescent history. Since Lower Cambrian times there is no evidence of igneous activity until the Tertiary, when volcanism on a very restricted scale is recognisable in the extreme northern and southern parts of the State. The absence of any signs of igneous activity during the immense period of time between the Lower Cambrian and Tertiary is, I think, one of the most remarkable features of Western Australian geology, especially when it is compared with the igneous record in Eastern Australia, and it emphasizes the extremely stable condition of the Western Australian shield throughout post-Cambrian times. There have undoubtedly been some oscillatory

movements of this continental block and slight folding and fracturing of the Palaeozoic and Mesozoic formations, but there is no evidence anywhere of violent diastrophisms or volcanism.

The events in the igneous history of Western Australia will now be considered, so far as possible in their chronological sequence.

II. THE PRE-CAMBRIAN SUCCESSION IN WESTERN AUSTRALIA.

Before proceeding to a consideration of the extensive igneous activity of Pre-Cambrian times it will be necessary to outline present views regarding the Pre-Cambrian succession. The latest opinions published regarding this matter are those of Forman (39) and Clarke (17 and 15) published in 1937, 1938 and 1931 respectively, and these are summarised in Table 1.

It will be seen that the successions as suggested by the two authors are in close agreement, the most outstanding difference being that Clarke has placed the Darling Gneiss Complex at the base of the succession, much against his will it seems, since he says (17, p. 21), "The writer inclines to the belief, based mainly on observations in the south of the Region [South-West Area of Western Australia], that the gneisses etc. of the Darling Complex are portions of the system next described [the Yilgarn-Kalgoorlie System] which have been extensively attacked and digested by acid intrusions. On the other hand Terrill considers (personal communication) that there is proof that the two systems are separated by an unconformity." The detailed succession for the Kalgoorlie District suggested by Forman (39, pp. xvii-xix) is indicated in Table 1, since this is the most completely investigated of the Pre-Cambrian areas of the State and further reference will be made to this section later.

Further work since the publication of Clarke's 1938 paper (17) necessitates some minor alterations to the succession and these are set down in the final column of Table 1. These amendments are:—

(a) The Stirling Range beds and Cardup Series, considered by both Clarke and Forman to be members of the Whitestone Series of Lower Archaeozoic age are transferred to the Proterozoic on the evidence yielded by further studies of these rocks (74, p. 51 and 19, p. 224). In connection with the position of the Stirling Range beds in the sequence it may be noted that Woolnough (102, p. 91) considers these beds to be intruded by granite but Clarke (personal communication) who has examined the area described by Woolnough has been unable to confirm the suggestion that the granite is intrusive into the Stirling Range beds and has found no evidence elsewhere in the Range that the granite is intrusive. The Stirling Range beds are therefore tentatively referred to the Nullagine period.

(b) The granitic rocks of late Archaeozoic age have been subdivided into two distinct groups:—(i) Older Granites belonging to an early period of granitization and granite intrusion under stress and (ii) Younger Granites of a later period of granite intrusion with which many of the State's metalliferous deposits appear to be genetically related. The evidence for this subdivision has been previously set down by the author (77). The granitic components of the migmatitic gneisses of the Darling Complex are included with the Older Granites rather than at the base of the succession as suggested by Clarke.

TABLE I.

THE PRE-CAMBRIAN SUCCESSION IN WESTERN AUSTRALIA.

AGE.	FORMAN (1937). W.A. Generally.	FORMAN (1937). Kalgoorlie District	CLARKE (1938).	PRIDER (1945).
LATE PROTEROZOIC or LOWER CAMBRIAN.	Basic dykes (epidiorite, dolerite, norite)	Dolerite and Gabbro	Basic dykes (epidiorite, dolerite, norite)—Probably feeders of Nullagine volcanics	Basic dykes (epidiorite, dolerite, norite) - Period of base metal ore formation.
	Igneous contact			
PROTEROZOIC.	Nullagine Series	Kurrawang Series	Nullagine Series	Nullagine Series (including Stirling Range beds and Cardup Series).
	Unconformity			
ARCHAEOZOIC.	Gneisses, granite and porphyry	Granite and porphyry	Later Granite invasion (major period of ore formation)	Younger Granite (period of auriferous ore formation and economically important pegmatites)
			Igneous contact	
				Older Granite (gneisses and migmatites)—Period of granitization.
	Igneous contact			
		Younger Greenstones	Yilgarn-Kalgoorlie System: Basic dykes [? Younger Greenstones]	Yilgarn-Kalgoorlie System: Younger Greenstone Phase (period of auriferous ore formation)
		Igneous contact		
		Kundana Series		
		Unconformity		
		White Flag Yindarlgoorda Series	Whitestone phase, including Stirling Range beds	Whitestone phase
	Whitestone Series (= Mosquito Creek Series = Jimperding and Cardup Series)			
		Unconformity		
		Black Flag—Tuffaceous Series		
	Greenstone Series (= Warrawoona Series)	Kalgoorlie Series (= Older Greenstones)	Older Greenstone phase	Older Greenstone phase
			Unconformity	
			Darling gneiss complex	

Prider (1945), Whitestone and Older Greenstone phases: Subdivision at Kalgoorlie as given by Forman, except that "White Flag-Yindarlgoorda Series" is replaced by "Yindarlgoorda Series" and "Black Flag-Tuffaceous Series" by "Black Flag Series."

(c) It is suggested that the Younger Greenstone period was a period of ore formation. The reasons for this addition are developed in a later section of this paper.

(d) Forman's "Black Flag—Tuffaceous Series" and "White Flag—Yindarlgoorda Series" of the Kalgoorlie District are replaced by "Black Flag Series" and "Yindarlgoorda Series" respectively.

III. ARCHAEOZOIC IGNEOUS ACTIVITY.

A. OF YILGARN-KALGOORLIE TIMES.

The rocks of the Yilgarn-Kalgoorlie System, the basal System in Western Australia, forming as they do the country of the more important auriferous deposits, have been more closely studied than those of later formations. Moreover some of these localities, because of their relatively greater economic importance, have been more intensively studied than others. These studies were begun in various widely spaced localities and different investigators have given different names to what are probably more or less contemporaneous formations. Much of this ambiguity has however been overcome by the recent work of Clarke (17 and 15) and Forman (39) which has been directed towards the correlation of these formations in the different parts of the State. In this present paper all the pre-granite formations are considered to belong to the Yilgarn-Kalgoorlie System and the igneous activity of these times will be considered from the record as seen first of all in the various natural regions (14) in the southern half of the State and then as developed in the northern half of the State.

1. SOUTH-WESTERN AUSTRALIA.

This region extends as far north as latitude 26° S. Within this part of the State are situated the more important gold-bearing areas (where there is an extensive development of the greenstone phase of the Yilgarn-Kalgoorlie System) and the important agricultural areas (where there is, so far as known at present, a predominance of granitic and gneissic rocks and the greenstone phase can only be detected in remnant structures).

(a) *Kalgoorlie and Murchison Natural Regions.*

Throughout the various mining fields which have been examined of later years, the oldest recognisable rocks are of volcanic origin and are generally referred to as the *Older Greenstone Series.* They are all metamorphosed to some extent and in many areas regional metasomatism, on which there is impressed a more intense local metasomatism in the vicinity of ore-bodies, has tended to reduce all varieties to a common end product. Nevertheless from their relict structures they can be seen to be largely basaltic lava flows (very often pillow lavas) with associated fragmental volcanic rocks. Of recent years the pillow structure of these basaltic rocks has been utilised in determining the stratigraphical order in the highly folded greenstones. Although pillow structure had been recognised much earlier (Honman for example in 1917 described pillow lavas from the Yerilla District (46, p. 26)) it was not until the American geologists of the Western Mining Corporation in about 1932 "rediscovered" these structures, that their use for unravelling structure was realised in Western Australia.

The least altered of these basic lavas are fine-grained amphibolites in which the pyroxenes of the original basalts have been replaced by pale green fibrous amphibole. With further metasomatism (propylitisation) the fine-grained amphibolites give way to fine-grained greenstones in which the amphibole is replaced by chlorite and progressive carbonate metasomatism is noticeable in the replacement of all rock minerals by various carbonates yielding rocks generally referred to as "calc schists." The fine grained amphibolites, in areas which have suffered high grade metamorphism, are represented by hornblende schists (schistose plagioclase amphibolites) in which the original basaltic textures are completely obscured by recrystallisation. The origin of such rocks however is often clearly indicated by the presence of pillow structure which is retained even in completely recrystallised rocks.

The most closely studied area of the Older Greenstone Series is in the vicinity of Kalgoorlie and the petrography of the fine-grained amphibolites, greenstones and calc schists of this area has been fully dealt with by Simpson and Gibson (89, pp. 16-21), Thomson (97, pp. 631-5), Feldtmann (29, pp. 17-23) and Stillwell (91, pp. 20-1).

In some areas a minor development of rhyolitic flows occurs interbedded with these basaltic lavas, thus in the Yerilla District of the North Coolgardie Goldfield, Honman (46, p. 25) describes a rhyolitic series which is contemporaneous with the basic lavas and occurs interbedded with them. The volcanic series developed at Yerilla consists predominantly of greenstones such as fine-grained amphibolites (very similar to those of Kalgoorlie) and amphibolite schists. Many of these greenstones have their volcanic characteristics—vesicular, amygdaloidal and pillow structures well preserved. Periods of explosive volcanism are represented by the agglomerates interbedded with the greenstones. Acid lavas are represented by a minor development of rhyolites also interbedded with the greenstones.

Mention of rhyolitic rocks occurring associated with fine-grained greenstones in many other mining districts is to be found in various publications from the Geological Survey of Western Australia but owing to the possibility that they are members of later series, such as the Black Flag and Yindarlgoorda volcanic series of the Kalgoorlie District (39, p. xix) these will not be considered here. The Yerilla rhyolites however appear to belong definitely to the Older Greenstones and indicate that acid lavas were extruded in the earliest part of the Archaeozoic Era.

In the goldmining areas situated west from Kalgoorlie the lavas of the Older Greenstone Series are represented by schistose amphibolites, the significance of which will be discussed later in dealing with the metamorphism of these rocks. In spite of the extensive recrystallisation of these rocks they still retain the characteristic pillow structure of the Older Greenstones. This pillow structure is very evident in the fine-grained amphibolites of Coolgardie and in the completely recrystallised schistose amphibolites in the vicinity of Southern Cross (27, p. 75. see also fig. 1) in which amygdaloidal structures are also retained. Ellis (27, p. 75) considers that fragmental volcanics (volcanic breccias and tuffs) are interbedded with the lavas of the Older Greenstone Series of Southern Cross. In the southern Yilgarn no acid lavas have been recognised but rhyolite-porphyries are present in the northern Yilgarn near Marda (4, p. 154) and are considered to be part of the volcanic Greenstone Series.

In most of the mining areas of the Central Goldfields the basaltic lavas of the Older Greenstones Series contain intercalated bands of sediments (generally jaspilites).

The Older Greenstone Series then, which is placed at the base of the geological succession in Western Australia, is a series of basaltic flows of spilitic character with associated basic agglomerates and tuffs and a minor development of sedimentary jaspilites and acid volcanics such as rhyolites and their associated tuffs and breccias. In view of the spilitic character and common occurrence of pillow structure, these lavas were probably largely submarine extrusions.

The later part of the Yilgarn-Kalgoorlie Period is characterised by various epochs of volcanicity. According to Forman (39, p. xix) there are several series intermediate in age between the Older and Younger Greenstones and these have been examined in detail in the country to the west, north and north-east of Kalgoorlie (92, 93). The *Black Flag Series* lies on top of the Older Greenstones and is composed of rhyolite—and probably trachyte-tuffs, tuff-agglomerates and tuff-breccias with occasional thin bands of lava and flow breccias and erosion sediments such as grits, quartzites and mudstones—the record then is one of explosive volcanism associated with acid extrusions. The rhyolitic phase of the upper part of the Older Greenstones that has been mentioned earlier may perhaps be related to the Black Flag Series since no information is available regarding the relationship, conformable or otherwise between the Black Flag and Older Greenstone Series, except that the Black Flag Series is higher in the succession.

Forman (39, p. xix) refers to this series as the Black Flag-Tuffaceous Series, since Feldtmann in an unpublished report (32) referred to these rocks as the Tuffaceous Series. In view of the fact that Feldtmann's report remains unpublished and that the name Black Flag Series was used by Gustafson and Miller (41, p. 293) for this group of rocks in work published early in 1937 prior to Forman's publication (39) of the hyphenated name, it is best to use the name which has priority, viz. Black Flag Series.

The Black Flag Series is overlain unconformably by the Yindarlgoorda Series. Forman (39, p. xix) refers to this series as the White Flag-Yindarlgoorda Series since he considers the White Flag Series as established by Talbot (described in an unpublished report (92)), to be the equivalent of the Yindarlgoorda Series of Bulong, described by Feldtmann as pebble breccias (30, p. 20). In the text of his publication Feldtmann does not mention the name Yindarlgoorda Series, but this name does appear on his published map (30, plate 1) and so can be regarded as published, and therefore having priority the name Yindarlgoorda Series should replace "White Flag Series" or "White Flag-Yindarlgoorda Series." The Yindarlgoorda Series consists of andesitic and dacitic lavas and associated agglomerates and tuffs with interbedded erosion sediments. The petrography of the volcanic members has been described by Fletcher in Talbot's report (92).

The only remaining series—the Kundana Series, lying unconformably on the Yindarlgoorda Series is one of erosion sediments without any evidence of igneous activity. The widespread volcanism of the early

Archaeozoic appears then to have died out after the extensive eruptions which yielded the Yindarlgoorda volcanics and there is no further record of igneous activity until the intrusion of the Younger Greenstone Series now to be described.

The Younger Greenstone Series represents a hypabyssal phase of basic magma intrusion which appears to be the final stage of the igneous activity of Yilgarn-Kalgoorlie times. Rocks of this group, intrusive into all the pre-existing formations are represented in most of the mining fields in the belt of country extending from Norseman through Kalgoorlie to Leonora and Laverton and thence to Wiluna and Forman (39, p. xxv) considers the Younger Greenstones to be developed in the Southern Cross District and in this assertion is supported by Ellis (27, p. 84). However the Younger Greenstones appear to be of minor development in the Yilgarn Goldfield. Their distinctive characteristics may have been largely obscured by metamorphism, which in this area is of higher grade than in the regions mentioned above, so that they can only be distinguished from the recrystallised older basalts with difficulty. The Younger Greenstone Series is not nearly so important economically as in the more eastern areas where, especially at Kalgoorlie, they form the country of nearly all the more important auriferous lodes.

The Younger Greenstone magma appears to have been extensively differentiated prior to intrusion and is represented by earlier ultrabasic intrusions, followed by a basic (doleritic phase) and later by an intermediate to acid phase. Members of each of these three main groups are developed in most of the mining centres in the belt of country mentioned but have been most closely studied at Kalgoorlie. As with the Older Greenstones there has been considerable alteration of the rocks by post-crystallisation earth movements together with regional and local metasomatism but in spite of such alteration the three main phases—ultrabasic. basic and acid can be recognised. At Kalgoorlie they are represented by:—

(i) Ultrabasic phase:—

(a) Serpentines and various metasomatised types such as talc-mesitite rocks and fuchsite-carbonate-quartz rocks considered to be derived from peridotites (29, p. 14 and pp. 35-8).

(b) Hornblendites and metasomatised types such as talc-chlorite-carbonate rocks and some fuchsite-carbonate-quartz rocks derived from pyroxenites (29, p. 14 and pp. 32-4).

(ii) Basic phase:—

Various low grade metamorphic products of dolerite and quartz dolerite. The least altered types are uralitised dolerites and uralitic quartz dolerites (91, p. 21) termed "amphibolites" and "epidiorites" by Feldtmann (29, p. 14) and "amphibolites" by Thomson (97). With increasing propylitization (chloritization, albitization and carbonatization) the original quartz dolerites are represented by various quartz dolerite greenstones and their highly carbonatized equivalents, the bleached quartz dolerite greenstones (97, pp. 646-54; 91, pp. 25-8; 29, pp. 27-9).

(iii) Intermediate to acid phase:—

Is represented by (i) chloritized hornblende porphyrites (91, p. 36) and a more acid group (ii) albite porphyries or keratophyres (97, p. 658; 91, p. 31) which are termed albite porphyrites by Feldtmann (29, p. 39).

Petrographic details regarding these rocks are given in the various references cited.

Thomson (97, p. 663) considers that the peridotites were the earliest intrusives, followed closely by the pyroxenites and, after an interval, by the quartz dolerite and its local variants. It is generally agreed that the hornblende porphyrites and albite porphyries occur as later dyke-intrusions. The hornblende porphyrites are, in my opinion, earlier than the albite prophyries (72). All of these rocks are considered by Thomson (97, p. 662), Feldtmann (29, p. 87), Stillwell (91, p. 60) and Prider (72) to be co-magmatic and to represent a magmatically differentiated series which has suffered low grade metamorphism and subsequent metasomatism. Gustafson and Miller (41, p. 314) on the other hand consider that the albite porphyries (and ore solutions) probably came from "the underlying granite batholith." When all the factors of occurrence, petrology and type of associated mineralisation (mentioned in a later section) are considered it appears most probable that the albite porphyries are genetically related to the greenstone rather than the later granite magmas.

The Younger Greenstone period was therefore a period of hypabyssal igneous activity of a basic magma. The earlier ultrabasic and basic phases appear to be largely sills or laccoliths (as at Kalgoorlie (41, p. 296) and Wiluna (5, p. 3)) whereas the later acid porphyry phase is represented by dyke intrusions.

(b) *Jarrah, Stirling and Wheat Belt Regions.*

Here the record of Yilgarn-Kalgoorlie igneous activity is very fragmentary, being represented only by xenolithic bands or lenses within a wide expanse of granitic gneisses or by thin layers interleaved with the metasediments which appear to be the Whitestone phase of the Yilgarn-Kalgoorlie system. This south-western corner of the State is made up essentially of Archaeozoic rocks which are dominantly gneissic and granitic in character, with a minor development of an older metasedimentary series which is considered to be the Whitestone phase of the Yilgarn-Kalgoorlie System. It must be noted however, that these para-schists are probably of greater extent than the known outcrops suggest, since much of the country is covered by weathering products. Professor Clarke informs me for example that there is a band of schists 30 miles wide between Pt. Ann and Hopetoun on the south coast. These whitestones have been intruded by later gneissic granites which contain numerous basic lenses and also remnants of the whitestones themselves.

Both the extensive areas of whitestones and greenstone xenoliths in the gneisses are pre-gneiss (76) and Forman (39, p. xxvi) considers it probable that the greenstones of Bolgart are lower in the succession than the whitestones of the Jimperding Series. The greenstones have only been studied in detail in a few areas. At Toodyay (76, p. 119) they occur as basic bands and lenses of various amphibolites which are considered to be the result of recrystallisation of earlier basic igneous rocks the

original structures of which have been completely obscured by recrystallisation. Lenses of hypersthenite and associated cordierite-anthophyllite rocks occur in the gneiss at Toodyay (73) and also small areas of banded quartz-magnetite-grunerite (and hypersthene) rocks (=metajaspilites). The whole assemblage of xenoliths in the gneiss may well be imagined to be highly metamorphosed derivatives of the older Greenstone Series which, in many places, contains interbedded jaspilites—the amphibolites being derived either from basaltic lavas or doleritic rocks, the hypersthenites representing the earlier ultrabasic phase of the Younger Greenstones. At Dangin (78) lenses of amphibolite and hypersthenite, identical in character with some Indian charnockites, are present and may be correlated with the Toodyay greenstones and therefore with the Kalgoorlie greenstones. These basic lenses are a characteristic feature of the gneisses of the south coast both to the east and west of Albany and of the gneisses of the south-west coast between Capes Leeuwin and Naturaliste. Carroll (10, p. 169) considers these basic lenses to be derived from tuffs. They have, however, been so thoroughly recrystallised that all original structures have been lost and I consider that the most that can be said of them with certainty is that they were derived from basic igneous rocks, but whether these were pyroclastics, lavas or hypabyssals is not determinable.

Evidence of igneous activity in the Whitestone phase of the Yilgarn-Kalgoorlie System of the South-West is to be seen in the Toodyay district in the form of schistose plagioclase amphibolites interleaved with the metamorphosed erosion sediments—these amphibolites (76, p. 104) may have been either flows or sills which have suffered the same high grade (sillimanite zone) metamorphism as the associated para-schists.

(c) *Warburton Natural Region.*

The main Pre-Cambrian rocks here are those of the Warburton Range area, the westernmost exposures of a Pre-Cambrian belt which extends in an easterly direction to the Musgrave and Everard Ranges in South Australia. There is too much doubt regarding the succession in this area to warrant any detailed consideration here. Talbot and Clarke have described an older series of greenstones comparable with the greenstones of the Central Goldfields (94, p. 118) but Forman (38) considered these greenstones to be representatives of the Nullagine System and in this was supported by petrological observations of R. W. Fletcher (35). Forman (39, p. xxiv) now considers that some of the greenstones which he formerly thought to be of Nullagine age should be referred to the older Pre-Cambrian. The occurrence at Mt. Aloysius in the eastern part of the Warburton area of charnockitic rocks (94, p. 129) makes it probable that the gneissic belt to the north of the Warburton Range is similar to the gneissic areas of the Wheat Belt of the South-West—the charnockitic rocks being similar to those from Dangin (78) which, earlier in this paper, have been regarded as remnants of the Yilgarn-Kalgoorlie System which have escaped complete assimilation during the Older Granite period. Whatever be the age of the Warburton Range greenstones there is evidence, in these charnockitic rocks, of very early Archaeozoic activity of a basic magma.

2. THE NORTH-WEST NATURAL REGION.

In this region there are two main series of rocks which are earlier than the granites and gneisses and therefore comparable in age to the Yilgarn-Kalgoorlie System. These are the Warrawoona Series (dominantly of greenstones) and the Mosquito Creek Series (of metasediments) and they are regarded by Forman (39) as contemporaneous with the Greenstone and Whitestone Series respectively.

Evidence of igneous activity of Yilgarn-Kalgoorlie times in the Pilbara is confined to the Warrawoona Series which is made up mainly of igneous rocks with a minor development of normal erosion sediments. With the recently published reports of the Aerial, Geological and Geophysical Survey of Northern Australia there has been an increase in our knowledge of the distribution and structure of these rocks but there is still very little information about their petrography.

The igneous rocks of the Warrawoona Series are similar in many respects to those of the Kalgoorlie (Older Greenstone) Series, consisting largely of fine-grained greenstones (basaltic lava flows) and acid volcanics such as felsites together with various acid and basic flow-breccias. In the sheared zones in which most of the mining centres are located, these volcanics are represented by various schists—chlorite-carbonate schists for example are regarded as the sheared and metasomatised equivalent of the fine-grained greenstones (basaltic lavas and tuffs (33, p. 3)). The acid phase seems to be more widely developed than in the Older Greenstones of the Central Goldfields areas where, as has been previously noted, acid volcanic rocks are, in a few places, interbedded with the greenstones. None of the workers in this region have attempted to draw up a typical section of the Warrawoona Series so that, from the literature and published maps it is difficult to learn anything regarding the order of extrusion of the different volcanic rocks. The early Archaeozoic in this region was however a period of extensive volcanism, as it was in the southern part of the State.

3. THE NORTH KIMBERLEY NATURAL REGION.

The Archaeozoic rocks of this region are even less known than those of the Pilbara and they have only been cursorily examined at a few mining centres. The pre-granite rocks of this region are made up of a variety of metasediments and basic lavas (including pillow lavas) with interbedded tuffs and rare quartz porphyries which may be either sills or flows. Finucane (in A.G.G.S.N.A. Western Australian Reports 27 and 29) states that these rocks are members of the Mosquito Creek Series but Forman (39, p. xxii) considers that in the vicinity of Hall's Creek in the East Kimberley Division the oldest rocks exposed are greenstones (basic lavas and tuffs) comparable to the Warrawoona Series of the Pilbara, which are overlain conformably by sediments comparable to the Mosquito Creek Series.

Too little is known of the distribution, structure and petrography of these rocks to warrant any further consideration of them here.

Conclusions.

It is evident from the foregoing that throughout the State the early Archaeozoic was a period of intense volcanism. The oldest recognisable rocks are of basaltic character, probably largely submarine flows characterised by pillow structure and interbedded with pyroclastics and cherty sediments. These basalts appear to be very uniform in character but during the later stages of this period of activity some acidic lavas were extruded. The succeeding periods of Yilgarn-Kalgoorlie igneous activity (Black Flag and Yindarlgoorda Series) were of extrusive type but of entirely different character being dominantly acid (rhyolitic and dacitic) lavas with a more extensive development of flow-breccias and pyroclastics, and being probably largely subaerial deposits as compared with the submarine extrusions of the earlier Archaeozoic. The final phase of Yilgarn-Kalgoorlie igneous activity was in the form of hypabyssal doleritic intrusions (the Younger Greenstone Series) characterised by considerable diversity in rock types due to magmatic differentiation All of these rocks have been altered to some extent, either metasomatically or by regional metamorphism consequent upon the widespread activity of granitic magma, the nature of which will now be discussed.

B. THE OLDER GRANITE PERIOD.

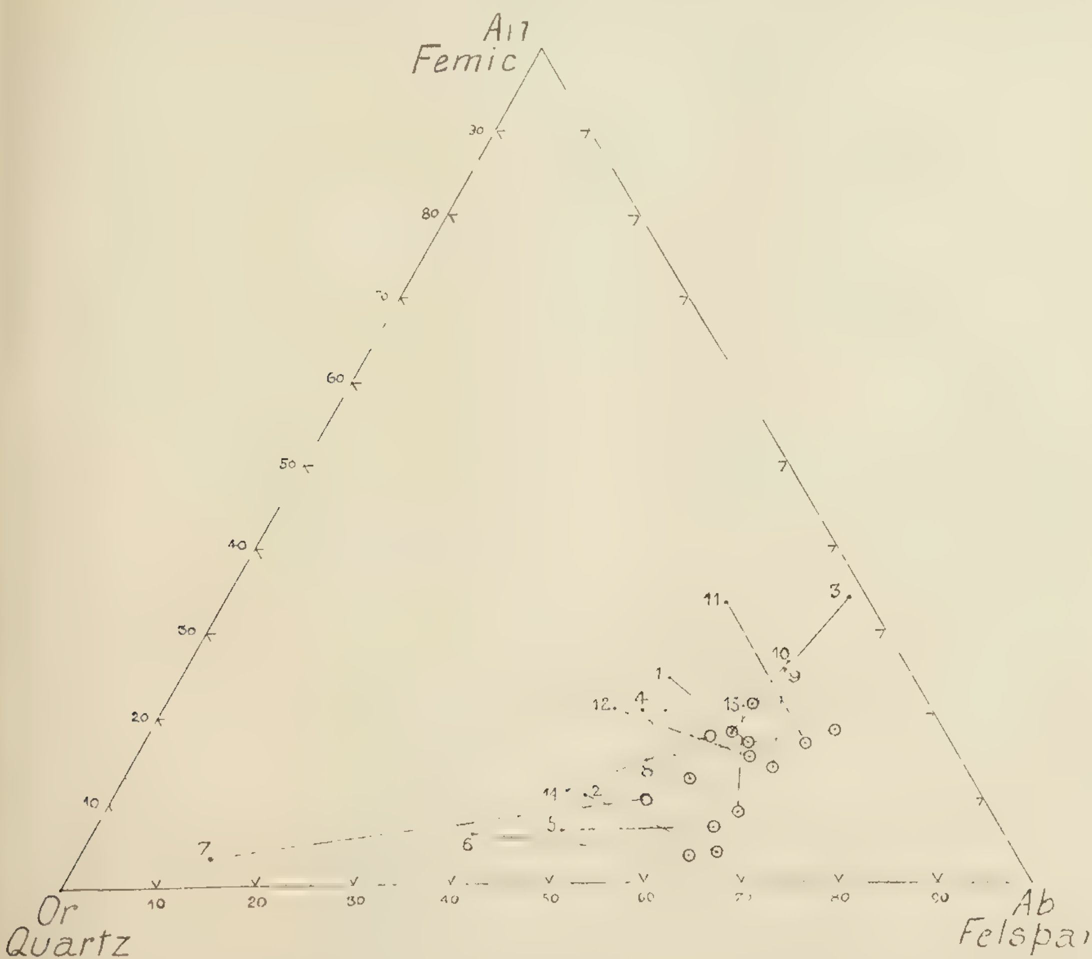
A glance at the latest (1933) geological map of Western Australia (40) will show that the greater part of the southern half of the State (south of latitude 26° S.) is made up of granitic rocks (granites and gneisses), enclosing comparatively narrow north-west trending strips of Yilgarn-Kalgoorlie rocks, and most Western Australian geologists are agreed that the granitic rocks are intrusive into the greenstones and associated sediments of the Yilgarn-Kalgoorlie System. Clarke (16, p. xl) has dealt with our changing conceptions of the nature of this "granitic" area of approximately 300,000 square miles, the present conception being that this area consists largely of a folded complex of Archaeozoic metamorphic rocks which have been extensively granitized to yield various gneisses and later intruded by granite stocks.

Of recent years evidence has accumulated which indicates that there are at least two distinct periods of granite emplacement (74, p. 29; 77; 27, p. 91; 76, p. 129). The earliest period, here referred to as the Older Granite, is now represented by granitic gneiss, probably the most extensive formation developed in South Western Australia, the later period (Younger Granite) being one of dyke and stock intrusions.

The gneisses of the Older Granite phase are largely of migmatitic nature showing considerable local variation in character due to assimilation of the older rocks whose original presence is indicated by the incompletely absorbed xenoliths. As mentioned previously these xenoliths may be correlated with rocks of the Yilgarn-Kalgoorlie System, from which they differ mainly in texture due to extensive recrystallisation during the period of migmatisation. These gneisses have been studied in detail in comparatively few localities. The Toodyay District is the best area yet studied for illustrating their relationships to the older rocks. Here they vary locally from potassic microcline granite gneisses to sodic oligoclase granite gneisses, and occur as large sill-like masses (one of which is estimated to be 5,400 feet thick) conformable with the associated meta-

sediments (76, p. 85). These gneisses contain numerous xenoliths of both metasedimentary and meta-igneous rocks (generally coarse hornblende granulites derived from older basic igneous rocks) and are similar in this respect to the gneissic complex wherever it has been studied. In the vicinity of such basic enclosures the granitic gneiss is often hybridised (76, p. 122) yielding more basic hornblende-bearing gneisses. In places where hypersthenites have been granitized the resultant rocks are cordierite-hypersthene-quartz-felspar gneisses, which would, except for the very clear demonstration of their origin as seen at Dangin (78), be normally regarded as metasedimentary rocks. These hypersthenites and related rocks are of charnockitic nature (78) closely resembling the charnockitic suite of India (44) and are fairly common in the gneissic complex (as for example at Northampton, Albany, Toodyay, Dangin, Fraser's Range and the country to the north-east of the Warburton Range).

The banding of the hybridised gneisses generally conforms to the bedding of the invaded metamorphic rocks. In the Toodyay gneisses this banding is due to a parallelism of xenoliths and to a parallel flow orientation of the microcline phenocrysts and the augen developed by protoclasis

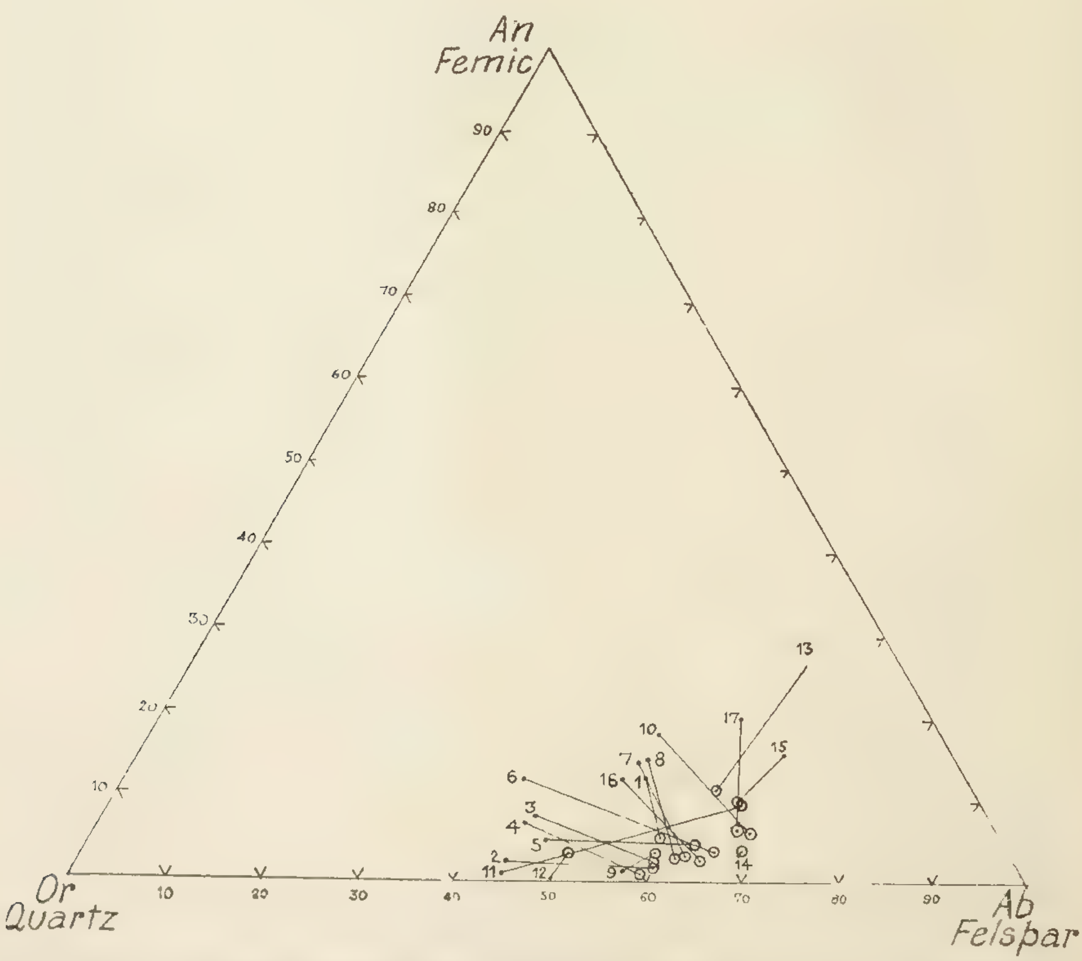


Text Fig. 1.—**Older Granites**—Larsen triangular diagrams (50) of rocks which appear to belong to the Older Granite period. Circles are quartz-felspar-femic ratios, dots are or-ab-an ratios. 1, Oligoclase granite gneiss, Toodyay (76, p. 110); 2, Microcline granite gneiss, Toodyay (76, p. 110); 3, Hornblende granite gneiss, Toodyay (76, p. 123); 4, Hybrid gneiss, Armadale (74, p. 36); 5, Granite gneiss, Russell Range (84); 6, Granite gneiss, Pine Hill, Russell Range (84); 7, Cordierite-hypersthene-quartz-felspar gneiss, Dangin (78). Nos. 8-14 are all recorded as "granodiorite" in the records of the W.A. Government Chemical Laboratory and the Geological Survey of W.A. I have not examined this group of rocks and there is some doubt as to whether they should be included with the Older or with the Younger Granites. They are from the following localities:—8, Mosquito Creek (83, p. 20); 9, Kookynie (83, p. 20); 10, Cue (83, p. 20); 11, Bowgada (84); 12, Jitarning (84); 13, Morawa (84); 14, Jibberding (84).

of these phenocrysts. From an examination of the fabric of these gneisses and the associated quartzites (76, p. 109) it appears that the emplacement of the Older Granite coincided with the orogenic period responsible for the metamorphism of the Yilgarn-Kalgoorlie System—the main period of constructive metamorphism in Western Australia.

The gneisses of the areas that have been mentioned (Toodyay and Dangin) are similar in all respects to those of most other parts of the Western Australian Pre-Cambrian complex. In view of their similarity of structure and relations to the older rocks there can be little doubt that they were all more or less of contemporaneous formation, as are the granitic gneisses of the North-West and North Kimberley Natural regions.

Much of the granitic gneiss appears to be orthogneiss but replacement gneisses and migmatitic gneisses resulting from the metasomatism and injection of the Yilgarn-Kalgoorlie System also cover extensive areas. The Older Granite period was, therefore, one of State-wide activity of a very mobile granitic fluid and granitization was a characteristic feature of the igneous activity of this period. The chemical characteristics of the Older Granites are illustrated in Text Fig. 1.



Text Fig. 2.—**Younger Granites**—Larsen triangular diagrams (50) of granites which appear to belong to the Younger Granites. Circles are quartz-felspar-femic ratios, dots are or-ab-an ratios. 1, Kookynie (84); 2, Southern Cross (83, p. 16); 3, Mulgine (84); 4, On No. 1 Rabbit Proof Fence at 69 miles north of Burracoppin (84); 5, Mt. Ridley (84); 6, Mahogany Creek (83, p. 18); 7, Boya (84); 8, Canning Dam (77, p. 144); 9, Gosnells (22, p. 254); 10, Mundaring (84); 11, Bannister (83, p. 18); 12, Norseman (83, p. 18); 13, Ravensthorpe (83, p. 20); 14, Fraser's Range (84); 15, Coolgardie (83, p. 16); 16, Beeragoona (84); 17, Buldania Rocks (84).

C. YOUNGER GRANITE.

The latest phase in the development of the granite and gneiss complex was the intrusion of massive granites in the form of stocks and dykes, accompanied by pegmatites, aplites and quartz veins. These granites transgress the gneissic structure of the Older Granites and the bedding and schistosity of the Yilgarn-Kalgoorlie rocks. They often enclose xenoliths of the older gneisses and in some instances (as in the Darling Range near Perth) there is such an intimate mixture of the older and younger granite phases that it is impossible to map them separately.

The Younger Granite in the Darling Range is characterised by its potassic character, microperthitic microcline being constantly present, but in other areas they are more sodic trondjhemitic types. The chemical composition of such granites which, from the available data, can reasonably be regarded as belonging to the Younger Granite series is graphically represented in Text Fig. 2.

The Younger Granite is accompanied by end phase quartz-felspar- and granite-porphyries, aplites, pegmatites and quartz veins. Many of these dykes and veins are economically important by virtue of their content of such minerals as gold, mica, felspar, cassiterite, tantalite and so on.

No detailed systematic examination of the Western Australian granites has yet been attempted and it is probable that there are a number of igneous epochs represented in this Younger Granite phase. Study of some granites from the Darling Range (77) indicates that some at least of the massive granites which are absolutely devoid of any visible directed structure and are the most normal looking of the Western Australian granites are of palingenetic origin, resulting from the rheomorphism of the Older Granites.

Much work remains to be done in connection with the origin and correlation of the Western Australian granitic rocks. In spite of the fact that they are the most ubiquitous rocks in the southern half of the State and that the emplacement of the granite masses was probably one of the most important geological events in Western Australia, since it was the major factor in the widespread metamorphism of the Archaeozoic formations and in the formation of many important ore deposits, the granitic rocks have not been closely studied. This is due in part to the fact that in inland Western Australia rock outcrops are generally poor, being largely obscured by weathering products, but also in part because it is not regarded as an economically important matter since the granitic rocks do not generally carry important auriferous deposits. However the possibility of the areas of granitized greenstones being potential auriferous country has been mentioned by Ellis (27, p. 14) and the occurrence of auriferous veins in the granitized gneisses of Westonia (61, p. 19), in the granite at Yarri (54, p. 6) and in the granite at Kundip near Ravensthorpe (personal observation) and doubtless in other places, in addition to the fact that the Younger Granites are the source of many other important metallic minerals, indicates that even on the economic score the granitic rocks are worthy of further attention. In addition it must be remembered that much of the agricultural areas is underlain by the granitic complex and now that it has been conclusively demonstrated that the minor elements play a very significant role in animal and plant nutrition a closer study of these rocks is well warranted because from them come the

mineral constituents of the soils. I would urge that when mineral deficiency problems are being studied in any particular area detailed geological surveys be undertaken together with petrological and chemical work on the rocks and that attempts be made to correlate such data with the results obtained from the plant and animal nutrition investigations. Failure to effect such correlation means that what is probably a very useful tool which may provide a short cut to the time-consuming methods at present practised, is being overlooked. In connection with such mineralogical investigations I feel that spectroscopic analysis of minerals separated from the underlying rocks would be invaluable in pointing to the nature of the deficient elements. Such work would undoubtedly yield data that would be useful in subsequent nutrition investigations in other areas and incidentally be useful in unravelling the history of the granitic complex.

As has been mentioned the weathered nature of outcrops is a difficulty that is encountered in inland Western Australia, but along the southern and south-western coasts excellent exposures of fresh rocks have been laid bare by marine erosion and close study of such exposures would yield much information about the Western Australian granitic rocks and the vexed question of granitization that has recently been so completely reviewed by Read (80).

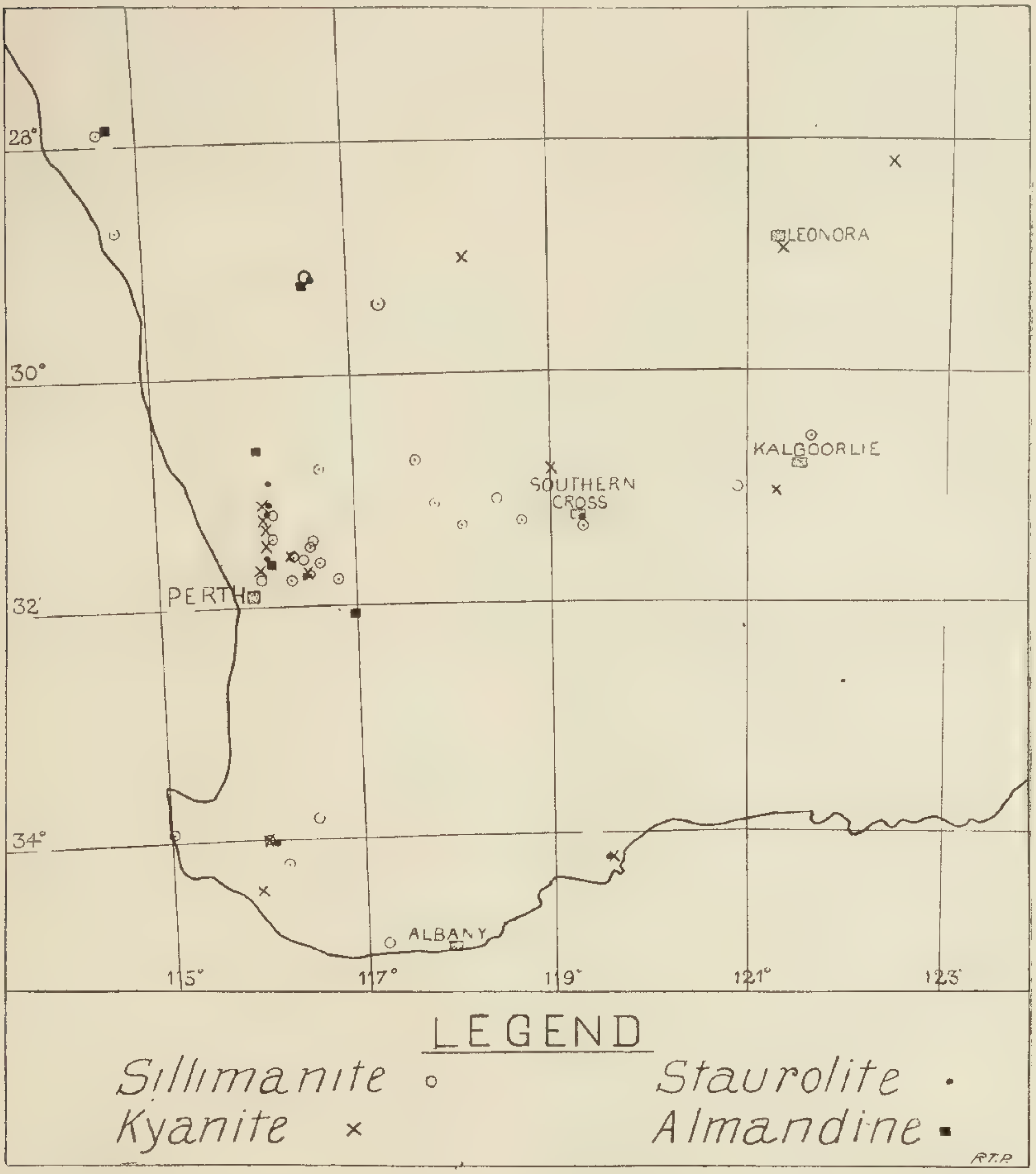
D. METAMORPHISM OF ARCHAEOZOIC ROCKS.

As has been indicated above the main period of orogenesis and constructive regional metamorphism was more or less contemporaneous with the emplacement of the Older Granites but in certain goldfields areas extensive regional and local metasomatism has been effective and earth movements of later age than the Younger Granites have brought about simple dynamic metamorphism of the older rocks. This latter is particularly noticeable in the granitic complex of the Darling Range near Perth, the rocks of which have, along numerous narrow shear zones, been converted into sericite schists as at Darlington (20, p. 174). This dynamic metamorphism is of comparatively late development being probably later than the Proterozoic basic igneous activity (20, p. 176) and will not be considered further here.

In view of the two markedly different types of metamorphism of Archaeozoic age it will be necessary to consider them separately thus:—

1. DYNAMOTHERMAL METAMORPHISM.

There is too little published petrographical information to allow of more than a very generalised account of regional metamorphism in Western Australia, a topic which has not, to my knowledge been previously discussed and I put forward these generalizations in the hope of provoking further inquiry. The detailed petrographic work that has been published has dealt with the more economically important greenstones, rocks, which although useful in a study of zonal metamorphism (100 and 70) do not yield such critical data as the pelitic sediments. Moreover the available petrographic data on the greenstones accumulated many years ago contains very few detailed optical data about the chlorites and amphiboles which are necessary if these greenstones are to be used as indicators of metamorphic grade (100).

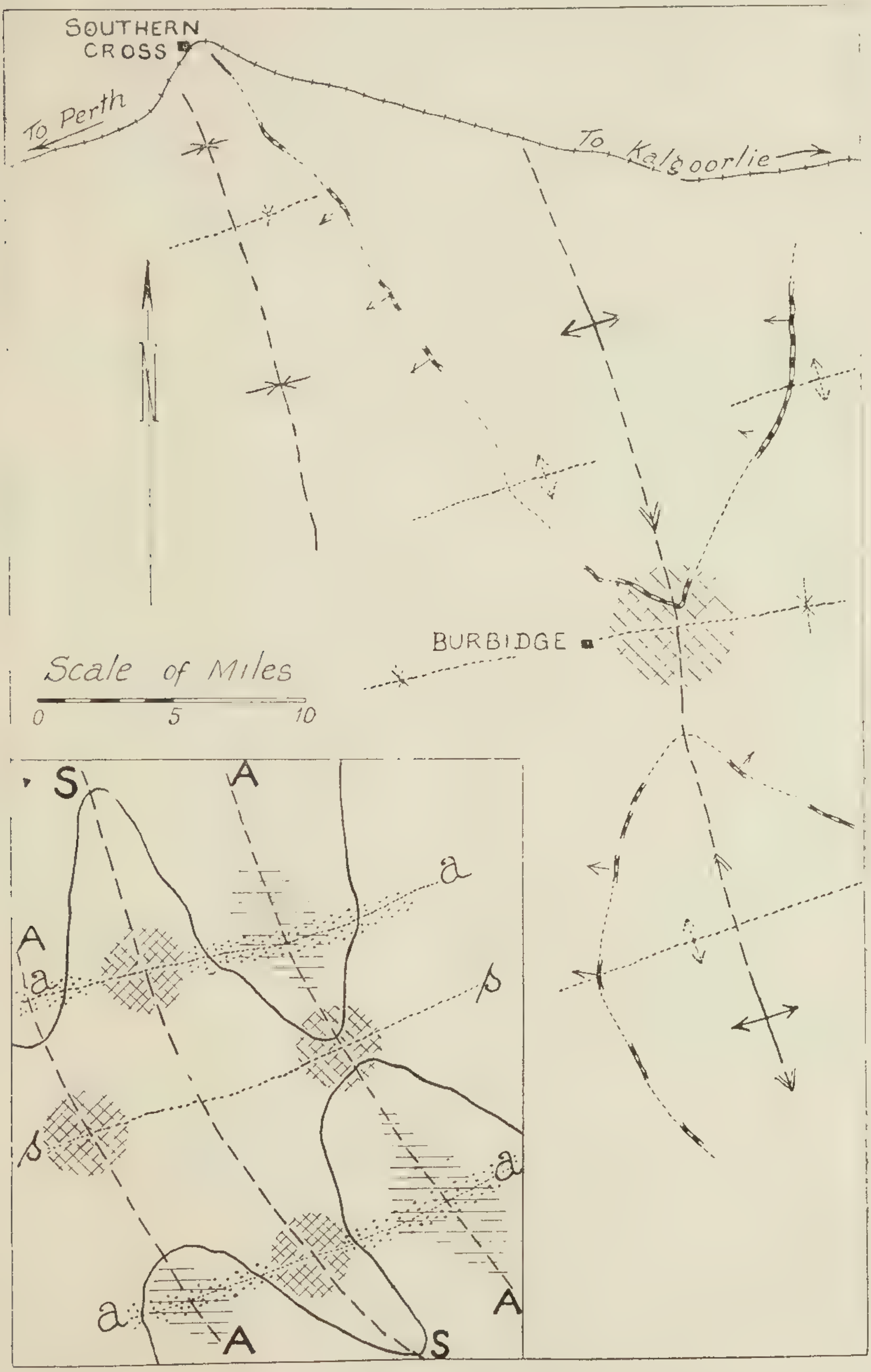


Text Fig. 3.—Sketch map of south Western Australia showing the known occurrences of the higher grade metamorphic index minerals (data from 88 and the rock collection of the Department of Geology of the University of Western Australia).

In dealing with regional metamorphism the southern half only of the State will be considered because of our almost complete ignorance of the petrography of the Archaeozoic formations in the northern part. As a starting point we may consider the known occurrences of the higher grade metamorphic index minerals in the southern part of the State. These occurrences are shown in Text fig. 3 and from their distribution it appears that the grade of metamorphism decreases from west to east. The more numerous occurrences of such index minerals towards the western margin of the Western Australia Pre-Cambrian shield may be partly due to these areas having been studied in more detail in certain parts than the goldfields areas which have been more broadly surveyed. Nevertheless from other considerations, as outlined below, I believe that the distribution of these index minerals as shown in figure 3 yields a true broad picture of regional metamorphism in the southern half of Western Australia, viz. that the grade of metamorphism decreases from west to east. A most noticeable feature is the high grade metamorphism of the Darling Range

and Yilgarn Goldfield rocks as compared with the very low grade metamorphism found at Kalgoorlie. The pelitic sedimentary phase of the Yilgarn-Kalgoorlie System in the Darling Range area is represented by sillimanite and kyanite-bearing schists and therefore belongs to the sillimanite zone. Sillimanite and kyanite are present in small amounts in the heavy fractions of soils from the Yilgarn Goldfield, sillimanite being more abundant than kyanite (27, p. 170) and Ellis (27, p. 68) records the presence of sillimanite schists in the Whitestone Series. In addition the greenstones of the Yilgarn are completely recrystallised schistose amphibolites which in places are garnetiferous and the jaspilites interbedded with the amphibolites have been completely recrystallised to banded quartz-magnetite-grunerite rocks similar to those of the Darling Range areas (68, p. 26). It is apparent therefore that the greater part of the Yilgarn area lies within the sillimanite zone. Farther east in the next exposed area of Yilgarn-Kalgoorlie rocks, the area extending from Bullabulling to beyond Bulong, the metamorphism is of much lower grade. Sillimanite gneisses are developed near the western margin of this area in a quarry alongside the railway line at the 332-mile peg approximately two miles west from Bullabulling and Carroll (9, p. 11) has recorded sillimanite and kyanite from the heavy residues of some soils from Bulong and Kanowna but elsewhere in the vicinity of Kalgoorlie, where there is an extensive development of pelitic and psammopelitic sediments, metamorphism is of very low grade and there has been no recrystallisation of the basic lavas and the sedimentary rocks which although as strongly folded as elsewhere in the State, are practically unaltered in character.

In the Mt. Margaret Goldfield according to Hobson (42, p. 16) "a noticeable feature is that the regional metamorphism is low in grade and almost entirely confined to dynamic or stress effects. Despite the relatively abundant development of sedimentary beds of a type which is usually fairly sensitive to changes in temperature and pressure conditions the only metamorphic minerals so far located in these beds are andalusite, chiastolite, staurolite and possibly corundum in several small occurrences, which are clearly due to the contact heating effects of local intrusions. A garnetiferous amphibolite has been recognised from the dump on 'Hutanui' G.M.L. 1679 but garnets are absent from the amphibolites elsewhere in the vicinity. Minerals such as kyanite and sillimanite are absent, as are also mica schists." Miles however (64, p. 10) has since described an occurrence of kyanite schist from the Camel Humps, approximately 33 miles north of Laverton. It is interesting to note that the Camel Humps kyanite-quartz schist and also the kyanite-andalusite-quartz schist of Mt. Leonora (64, p. 14) are comparatively close to the granitic and gneissic rocks (similar to the occurrence of sillimanite gneiss at Bullabulling in the Coolgardie Goldfield) and it appears that in these Central Goldfields areas the grade of regional metamorphism is high in the vicinity of the granitic gneisses and low in places remote from the granitic rocks. Kalgoorlie itself lies in the centre of an area of approximately 8,000 square miles of Yilgarn-Kalgoorlie System rocks (see 40) and although the formations have been very strongly (isoclinally) folded so that all dip, on the average, about 70° to 80° to the west, because of its remoteness from the granitic rocks the heat factor has been low and the rocks show no evidence of constructive metamorphism. Metasomatism, as discussed in the next section, has however produced marked changes in the rocks of the Kalgoorlie area.



Text Fig. 4.—Structural sketch map of the southern part of the Yilgarn Goldfield showing the outcrop of the metajaspilite horizon. The structure is a main NNW trending anticline overturned to the east and crossed by ENE crossfolds. *After Ellis* (27, plate 2). The area of most intense metamorphism in the vicinity of Burbidge (according to R. S. Matheson) is shown by crosshatching. Inset is a diagrammatic structural plan of such an area with main NNW trending anticlines (A) and synclines (B) with minor crossfolds (anticlines *a* and synclines *s*), showing the most favourable parts of such structures for gold deposition (dotted), intense metamorphism (crosshatched) and granitization (horizontally ruled).

It has recently been discovered that cross-folding on more or less east-west axes has been superimposed on the main north-west trending folds in the Central Goldfields areas. What affect has this cross folding had on the rocks? The influence of such crossfolding in forming loci for ore-deposition in the Yilgarn Goldfield has been described by Ellis (27, pp. 134-147), the most favourable locations being where the main N.W. trending anticlinal folds are traversed by easterly trending anticlinal cross-folds. Mr. R. S. Matheson of the Geological Survey of Western Australia informs me that he considers that the cross-folding along more or less east-west axes, superimposed on the main N.W. trending folds, has been an important factor, not only in the location of auriferous deposits but in determining the grade of metamorphism and also the degree of granitization to which the rocks have been subjected. Thus, according to him the most intense area of metamorphism in the Southern Yilgarn is in the vicinity of Burbidge (see fig. 4) where the structure consists of a main N.W. trending anticline crossed by an east-west synclinal cross-fold. He suggests that the more intense metamorphism of this area is due to the pressure being greater in such a structure than in structures such as anticlines crossed by anticlinal cross-folds. In the latter structure tension is the predominant force, leading to the formation of rock openings which have later been filled by ore solutions; in such areas granitization is more extensive than in the higher pressure areas where recrystallization of the rocks is the dominant process. These suggestions concerning the distribution of highly metamorphosed areas, granitized areas and the most favourable areas for ore deposition are illustrated diagrammatically in Text fig. 4.

2. METASOMATIC METAMORPHISM.

Regional metasomatism is a marked feature of some of the Western Australian mining districts, especially those lying within the belt of country extending from Kalgoorlie to Wiluna. This metasomatism has been most closely studied at Kalgoorlie where practically all the greenstones (both Older and Younger) have been regionally albitized and carbonatized. The process is essentially one of propylitization due to the introduction of carbonic solutions or vapours which were probably a late-stage product of the Younger Greenstone magma. This regional metasomatism has been followed by more intense local alteration along zones of weakness by somewhat similar but more siliceous ore solutions yielding the auriferous lode formations which are shear zones that have been intensely metasomatized by the introduction of carbon-dioxide, sulphur, silica and potash. The regional and local metasomatism of the rocks of the Kalgoorlie District has been fully described by Stillwell (91, pp. 50-59) and by Clarke and Ellis (18, pp. 781-785) who have also described the type of metasomatism associated with ore formation in other mining areas. Miles (67) has recently discussed the nature of metasomatic changes near the Corinthian ore-body in the Yilgarn Goldfield—effects which are only noticeable within several feet of the auriferous veins. This very localised type of metasomatism, which leads to the development of biotite in the schistose amphibolite country rocks appears to be the most common type of change in the vicinity of the auriferous veins of the Yilgarn Goldfield generally.

E. ORE FORMATION.

Considered from the economic viewpoint the most important result of Archaeozoic igneous activity in Western Australia has been the formation of the various ore deposits which have played an important role in the

economic development of the State. With but one or two exceptions all the primary metalliferous deposits in Western Australia were formed in Pre-Cambrian times as the aftermath of igneous activity and as there has been a number of distinct periods of such activity it is pertinent to inquire here regarding the relationship between ore deposition and such igneous activity. Simpson (87) has provided a lead in this connection by delineating the various metalliferous provinces and dealing with epochs of mineralization in the State, but I should like to set down a few additional observations, dealing especially with the auriferous deposits.

1. AURIFEROUS MINERALIZATION.

The distribution of the gold deposits has been dealt with by Simpson (87) and the geology of these deposits has been outlined by Maitland (56). Since the publication of Maitland's work there have been notable advances in knowledge of the relationship between structure and ore deposition and in recent years some of the mining areas have been re-surveyed, particular attention being given to structural considerations. The rock structure is undoubtedly a very important factor controlling the location of ore deposits but it is equally important that there be a source of mineralizing solutions. Simpson (87, p. 215) considers that the gold-bearing solutions were derived from granitic magma and this appears to be the general opinion of Western Australian geologists.

When however we look closely at mineral associations within the ore-bodies and the associated metasomatic phenomena it is evident that there are several very distinct types of ore deposit thus:—

(i) The sulphide-bearing lode formations associated with extensive silica-carbonate metasomatism of the country rocks as exemplified by the lodes of the Golden Mile at Kalgoorlie.

(ii) The auriferous quartz reefs, which although they may occur in similar country to (i) are characterized by very slight potash-silica metasomatism of the country rocks. The auriferous bodies of the Yilgarn Goldfield are typical. Closely allied to this type are the porphyry dykes traversed by networks of contemporaneous auriferous quartz veinlets as at the Tindals Mine, Coolgardie, and the Patricia Mine at Edjudina.

There must be some reason for such difference—either it is due to a different source for the ore-solutions or they must have travelled different distances from the parent source. Simpson (87, p. 215) considers that the "earliest gold veins, such as those of Kalgoorlie, Meekatharra and Wiluna are invariably closely connected with large porphyry dykes . . . . not associated with pegmatite veins, being characteristic of an earlier and hotter period of igneous intrusion, causing extensive metasomatism along the zones of fracture." At the same time Simpson considers that the ultimate source of all the gold was a granitic magma. I am inclined to the view that the sulphide-bearing lode-formations associated with extensive carbonate metasomatism of the country rocks are genetically related to the Younger Greenstone magma whereas the quartz reef type were most probably derived from some granitic magma. The suggestion that these lode formations are related to the greenstone magma is not a novel one since it was put forward in the first instance by Thomson (97, p. 670) but appears to have been overlooked by later authors. As has been noted earlier there has been a marked tendency to differentiation of the Younger Greenstone magma. This has lead to a sodic end-phase which in addition to yielding the albite porphyries has effected albitization of the greenstones and this in turn was followed by the activity of carbonic solutions

or vapours, representing a later product of the greenstone magma, which has caused widespread metasomatic changes in the earlier rocks of the series. The final stage of activity of the Younger Greenstone magma was the more intense or rather localized action of such carbonic solutions along shear zones bringing about the formation of the lodes. All investigators of Kalgoorlie geology are agreed that the ore-bearing solutions come from the same magma as the albite porphyries but some (41, p. 314) consider that these porphyries are offshoots from an underlying granite batholith. The genetic relation of the albite porphyries to the Younger Greenstone magma has been discussed previously and if such relation exists, as seems highly probable, then the Younger Greenstone period must be regarded as one of ore formation.

The auriferous quartz veins and porphyries, on the other hand, appear to be derivatives of a granite magma. Ellis (27, p. 149) considers that the auriferous quartz reefs of the Yilgarn Goldfield are related to the "granite magma which has intruded the folded rocks of the Yilgarn System as batholiths," i.e. the Younger Granite of this paper. It is interesting to note however that throughout the Yilgarn the auriferous quartz reefs are invaded by pegmatite dykes (27, p. 88) which appear to be the end-phase derivatives of the Younger Granite and this throws some doubt on the suggestion that the auriferous reefs are related to the Younger Granite. It may indicate that there were a number of distinct periods of Younger Granite invasion.

It is interesting to notice also that Matheson (61, p. 21) considers that the auriferous reefs of the Edna May Mine at Westonia were formed prior to the granitization (i.e. Older Granite period) of this belt of country. If this be so then it is evident that the Edna May reefs are much older than all of the granites.

It is evident therefore that our knowledge of the time relations of auriferous mineralization in Western Australia is very meagre. It is probable that there were at least two distinct periods, one related to the Younger Greenstone magma, the other in some way related to the granite intrusions of the late Archaeozoic. Both types may occur in the same area, thus at Kalgoorlie there are the lodes of the greenstone magma type developed on the Golden Mile and the distinctly different felspar porphyry dykes with auriferous quartz veinlets a few miles to the west near Binduli (45, p. 41) and a few miles to the south-east at Golden Ridge (56, p. 73). Because these two contrasted types occur within the same comparatively restricted area we should not be led immediately to the conclusion that they come from the same source.

2. NON-AURIFEROUS MINERALIZATION.

Metals such as silver, copper, arsenic and antimony are produced as by-products in the treatment of auriferous ores and so will not be considered here. All the important non-auriferous mineral deposits except those of iron, copper and lead appear to be genetically related to the Younger Granites. The economically important iron ores such as those of Yampi Sound (8) and Koolyanobbing do not appear to be of magmatic origin but to be metamorphosed sedimentary formations, and the copper and lead deposits some of which occur in post-granite rocks must, in part, be associated with a later period of activity than the granite. Lead deposits occur in Archaeozoic country rocks in the vicinity of Northampton and are regarded by Feldtmann (31, p. 26) as genetically related to the acid pegmatites of this area and thus to the granitic magma. Gibb

Maitland on the other hand considers the Northampton lead deposits to be related to the epidiorites (53, p. 8) which Feldtmann considers are older than the pegmatites (31, p. 27). Whatever be the parent source of these lead deposits, the lead fields of the North-West Natural Region indicate important lead mineralization of post-granite age.

The important deposits related to the Younger Granite include those of tin, tungsten, molybdenum, tantalum and niobium, beryllium, lithium, radioactive minerals and such minerals as mica and felspar. All these are confined largely to the end-phase pegmatites of the Younger Granite magma and the distribution of most of these has been described by Simpson (87). Simpson (81) considers these minerals do not as a rule occur in the orthoclase or microcline pegmatites associated with potash granites such as those of the Northampton or the Darling Ranges but are almost invariably to be found in the albite pegmatites associated with soda granites, such as are seen at Wodgina and Moolyella in the North-West or Ravensthorpe in the south. Speaking of the distribution of rare metals in Western Australia (82, p. 87) he says that "such pegmatites [albite pegmatites] are the typical homes of the rare alkalie metals and the rare earth metals of the cerium and yttrium type, as well as tantalum, niobium, beryllium and uranium."

The present day development of new alloys incorporating many of these metals should lead to the more intensive exploitation of such deposits and stimulate the closer study of the granitic complex and in this regard spectoscopic analyses for the minor constituents of rocks of this complex in conjunction with detailed petrographic investigation would undoubtedly be of great economic and scientific value.

IV. PROTEROZOIC IGNEOUS ACTIVITY.

There are two phases of igneous activity in Proterozoic times (i) An earlier volcanic phase represented by various lavas and pyroclastics interbedded with the sediments of the Nullagine Series and (ii) a later hypabyssal phase represented by dolerite dyke and sill intrusions.

A. VOLCANISM OF NULLAGINE TIMES.

The Nullagine System is extensively developed in the northern half of the State where it unconformably overlies the metamorphic and granitic rocks. The System consists broadly of clastic sediments with interbedded lavas and tuffs and also contains doleritic sills. As far as can be gleaned from published data there is considerable variation in the succession from place to place. The most completely studied section is in the vicinity of Nullagine township and has been described by Maitland (55, pp. 120-130). The volcanic rocks include bedded amygdaloidal lavas, ash and agglomerate which occur at different horizons within the series. The section across the valley of the Nullagine River given by Maitland (55, plate 8) shows the occurrence of these volcanics at three horizons. Maitland states (55, p. 128) that wherever these volcanics have been examined it has been invariably found that they consist of acidic lavas and that each band consists of separate lava flows, each of no great thickness. Higher up in the series the conglomerates, sandstones, felsitic lavas and ash are overlain by limestones (plate XIII. of G.S.W.A. Bull. 33 shows a generalised section of the Nullagine Series in the West Pilbara) which is well exposed at Carawine Pool on the Oakover River. Here the limestones rest on basic

lavas (55, p. 26). It appears therefore that in late Nullagine times basic lavas were extruded. At Braeside the country rocks of the lead-bearing veins are a series of basic lava flows which are regarded by Finucane (34) as belonging to the Nullagine Series. These basic lavas contain interbedded limestones and are probably comparable to those at Carawine Pool. At Braeside the individual basic flows average about 80 feet in thickness, being fine-grained at the base of the flow, medium-grained at 20 or 30 feet above the base and highly amygdaloidal over the upper 20 feet. To the west of Braeside the basic lavas are overlain conformably by a considerable thickness of shales, sandstones and grits with occasional interbedded bands of volcanic ash and porphyry while to the east the basic lavas are overlain by "quartz porphyry and quartz-felspar porphyry flows" (34, p. 3).

Although from data at present available it is difficult to draw up a stratigraphical table for the Nullagine System it appears that, so far as igneous activity in the Pilbara region is concerned, it took place at intervals throughout Nullagine times, being volcanic and frequently explosive. The earliest eruptions were acidic, giving way to basaltic eruptions in middle Nullagine times and towards late Nullagine times again becoming acidic and of explosive character.

The Nullagine Series is also widespread in the North Kimberley. Over the greater part of this region the outcropping rocks consist of basaltic lava flows interbedded with massive sandstones of Nullagine age which are either horizontal or gently folded. Maitland (52, p. 9) refers to the igneous rocks as "a series of bedded and intrusive igneous rocks, the prevailing types being andesite, dolerite and diabase . . . . beds of volcanic ash and breccia are common in certain localities," and he considers that some at least of these basic rocks are sills. Edwards (25) has recently described all the available basaltic rocks from the North Kimberley and has distinguished a number of sub-groups which however are all of tholeiitic type. There appear to be two main groups: (i) the fine-grained interbedded basaltic rocks which tend to be andesitic in character and (ii) the coarser dolerites which may probably be from the dolerite dykes which intrude the lavas (52, p. 9).

The felsitic lavas which are so common in the Nullagine Series in the North-West region do not appear to be developed in the North Kimberley region.

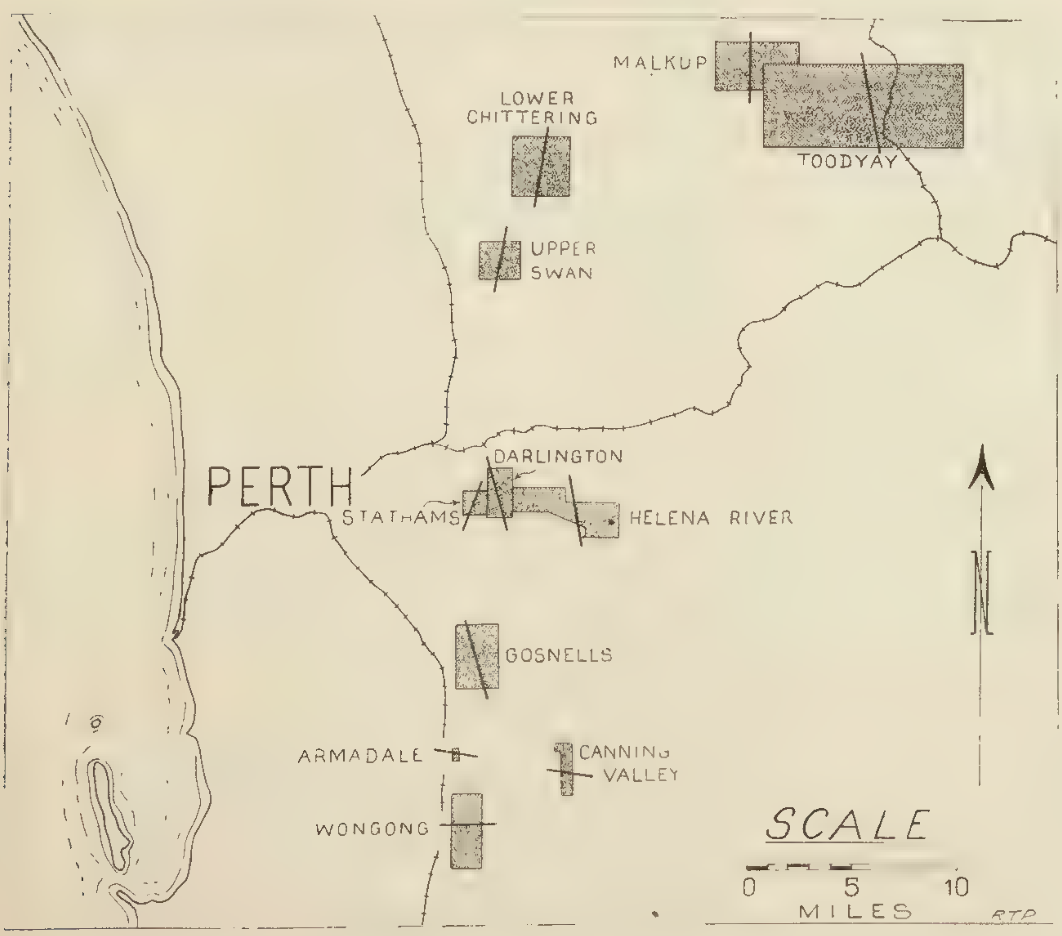
The Nullagine Series is also developed in the Warburton Region. Forman (39, p. xxiv.) now considers that the base of the Nullagine System in this area should be placed below the Warburton Range porphyries. Therefore in this area we have the earlier Proterozoic felsitic flows or sills similar to those of the Nullagine Series of the Pilbara. Higher in the succession in the Warburton Range area volcanism is represented by altered basaltic lavas (94, p. 135) probably belonging to the same stage of the Nullagine as the basaltic lavas of Braeside in the Pilbara (34).

The Nullagine Series in the south-western part of the State is thought to be represented by the Stirling Range beds and the Cardup Series. The Stirling Range beds contain no evidence of contemporaneous igneous activity. The Cardup Series at Armadale and various other localities along the Darling Scarp contains a conformable albite epidiorite sill or flow (74, p. 43) which is regarded as being older than the dolerite dykes

of this area. Since it shows a comparable grade of metamorphism to the associated sediments it is probably older than the earth movements which have affected the Cardup Series.

B. LATE NULLAGINE DYKE INTRUSIONS.

Throughout the State wherever Pre-Cambrian formations are developed there is a series of quartz dolerite dyke intrusions which traverse all the previously considered formations including the Nullagine Series, as in places they can be seen intruding the basic lavas of the Nullagine Series, e.g. at Braeside (34, p. 5). These basic intrusives have nowhere been found to penetrate the Palaeozoic formations but, in the Kimberley Division they may have been the feeding channels for the Cambrian lava flows. This possibility is considered in a later section of this paper. In the South-West part of the State the only evidence regarding time of intrusion of these quartz dolerites is that they are later than the granite and also intrusive into the Cardup Series (74, p. 31) and the Stirling Range beds (102, p. 92), while in the Central Goldfields they are post-gold and for this reason have not been closely studied since they do not in any way affect the tenor of ore-bodies.



Text Fig. 5.—Sketch map showing areas in the Darling Range which have been mapped in detail and the average trend of the quartz dolerite and epidiorite dykes. In general the dykes trend in a northerly direction but note the marked change to an east-west trend in the country to the south of Armadale.

Manifestations of this period of igneous activity are particularly well developed in the Darling Range area and it is in this region that they have been most closely studied. The dykes here form a well-defined swarm which in the northern parts of the range have a N.N.E. trend, in the centre a northerly trend and towards the south an E.S.E. trend. Near Perth these dykes have been quarried for road metal and the quarries so opened up indicate that the dykes dip steeply either to the east or to the west. Up to the present they have been mapped closely in eleven rather discontinuous areas, with a total area of 100 square miles only, so that until these surveys have been extended to embrace a wider area no definite statement can be made concerning their tectonic significance. They appear however to be related to an uparching of the Pre-Cambrian shield with the development of steeply dipping tensional fractures along which the basic magma has arisen. The amounts of crustal stretch due to dyke intrusion in the various areas near the Darling Scarp that have been mapped in detail are seen in the following table in which the areas are arranged from north to south. (See text Fig. 5).

"Area" and Reference.	Breadth Examined.	No. of Dykes.	Average Trend.	Aggregate Thickness. of Dykes.	Amount of Crustal Stretch.
	chains.			chains.	
Lower Chittering (63) ...	160	16	N. 10° E.	18	1 in 8·9
Upper Swan (37)	200	15	N. 10° E.	16	1 in 12·5
Darlington (20)	160	24	N. 15° W.	18	1 in 6·7
Helena River (6)	400	24	N. 10° W.	20	1 in 20·0
Stathams (unpublished) ...	80	6	N. 25° E.	11	1 in 7·3
Gosnells (22)	110	10	N. 10° W.	12	1 in 8·2
Armadale (74)	60	7	N. 80° W.	$7\frac{1}{2}$	1 in 8·0
Canning Valley (6)	280	15	N. 80° W.	21	1 in 13·3
Wongong-Cardup (95) ...	346	11	W.	22	1 in 15·7
Malkup (21)	400	24	N.	27	1 in 14·8
Toodyay (76)...	960	24	N. 10° W.	44	1 in 21·8

The Toodyay and Malkup areas are situated farther inland than the other areas mentioned and have been added to the table to indicate the tendency of the dyke intensity to decrease with distance from the Darling Scarp. In the goldfields and wheat belt areas still further east these dykes, although present, are not nearly so abundant.

A rather remarkable feature of the geology of the south-west part of the State is the absence of this dyke swarm from the country lying to the west of the trough extending from Geographe Bay to Flinders Bay. Although considerable geological work has been done in this area, no dolerite dykes have been encountered. Professor Clarke and Mr. H. T. Phillipps inform me that these dykes are also scarce in those parts of the coastal areas extending from Nornalup to Doubtful Island Bay which they have examined, but near West Cape Howe the coastal cliffs which in places rise approximately 200 feet almost vertically from the sea (Text Fig. 6), are composed of this dolerite which seems to lie on a basement of

Text Fig. 6.—Dolerite forming coastal cliffs approximately 200 feet high at West Cape Howe on the south coast some 20 miles west from Albany.
Photo—H. T. Phillips.

gneiss—this extensive outcrop, probably the largest yet noted of the quartz dolerite, appears to be a sill but the cliffs are too inaccessible for any detailed examination.

Petrographically the rocks of this period are nearly everywhere normal quartz dolerites (or gabbros) which, while generally unaltered, may in places be partially uralitised. Petrographic details of these rocks have been given in various publications (74, pp. 44-8; 76, pp. 125-7; 25, pp. 82-3) and Fletcher (36) has considered the petrology of the basic dykes of the South-West in some detail.

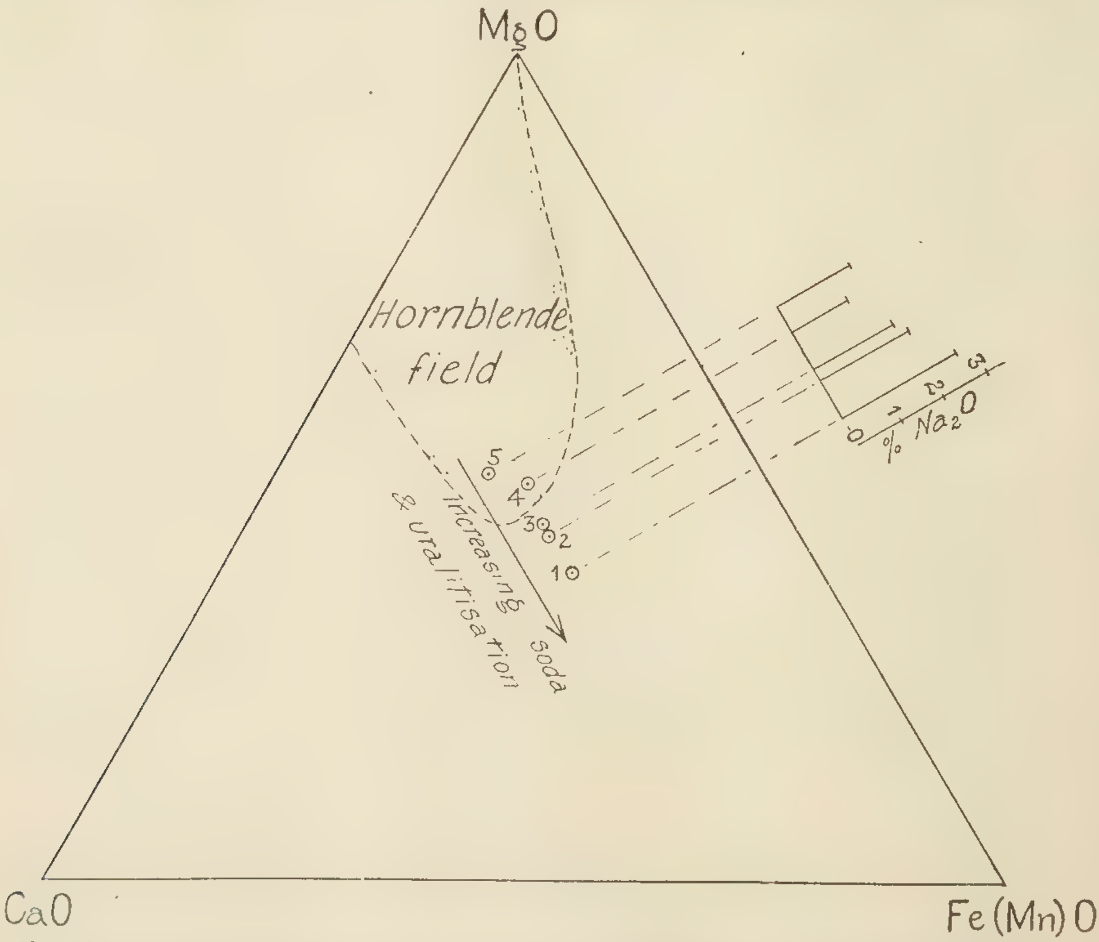
Members of the group differing from the normal type include:—

(i) *Olivine dolerites*: These are of rare occurrence and have been recorded only from the following localities:—Norseman (7, p. 29), Toodyay (76, p. 127), Newfield in the Yilgarn G.F. (65), Pope's Hill Siding approximately 60 miles north-west from Southern Cross (unpublished), near Bentley Hill in the Warburton Region (94, p. 182), and Pt. Irby and Point Hood on the south coast (unpublished). Simpson has also recorded (86, p. 116) a fayalite gabbro from Burge's Find but it is doubtful whether this is genetically related to the quartz dolerites. The picrites of Kalgoorlie and St. Ives (28) may belong to the olivine dolerite group.

(ii) *Biotitic epidiorites*: Very rare and only recorded from the Darling Scarp (74, p. 46) where they occur in narrow dykes or as an edge phase of the epidiorite dykes described below.

(iii) *Epidiorites*: These are abundantly developed in the Darling Scarp area within a radius of approximately 10 miles from Darlington. Outside this area the rocks are either uralitised quartz dolerites or unaltered quartz dolerites. These epidiorites differ from the dolerites in that blue-green hornblende is developed to the exclusion of pyroxene—the

reason for this development of hornblende in this particular area is not apparent. A plot of the MgO-CaO-FeO ratios of the available analyses of dolerites and epidiorites of the Darling Range near Perth by the method outlined by Kennedy (49) is shown in Text Fig. 7. The least uralitised rock No. 5 (from Toodyay) lies within the hornblende field, that containing blue-green hornblende to the exclusion of pyroxene No. 1 (from Smith's Mill) lies most distant from the hornblende field. This indicates therefore that the basic oxide ratios have not been responsible for the crystallization of the hornblende. In addition Kennedy has noted (49, p. 207) that the presence of water alone cannot control the nature of the ferromagnesian crystallization. The few available analyses seem to indicate that with increasing uralitisation there is an increase in the alkali (especially soda) content as indicated in Fig. 7, so that this process should be more marked in the later crystallizing rocks of this suite. In the epidiorite area within a 10-mile radius of Darlington, there appears to have been a recrystallization of the uralite to blue-green hornblende and the fact that soda has entered into the hornblende is seen in the stronger bluish-green colour at the borders of the hornblende prisms. Another characteristic of these epidiorites which is shared to some extent also by the uralitised dolerites, is the presence of smoky felspars which according to MacGregor (51) indicates that the enclosing rock has been



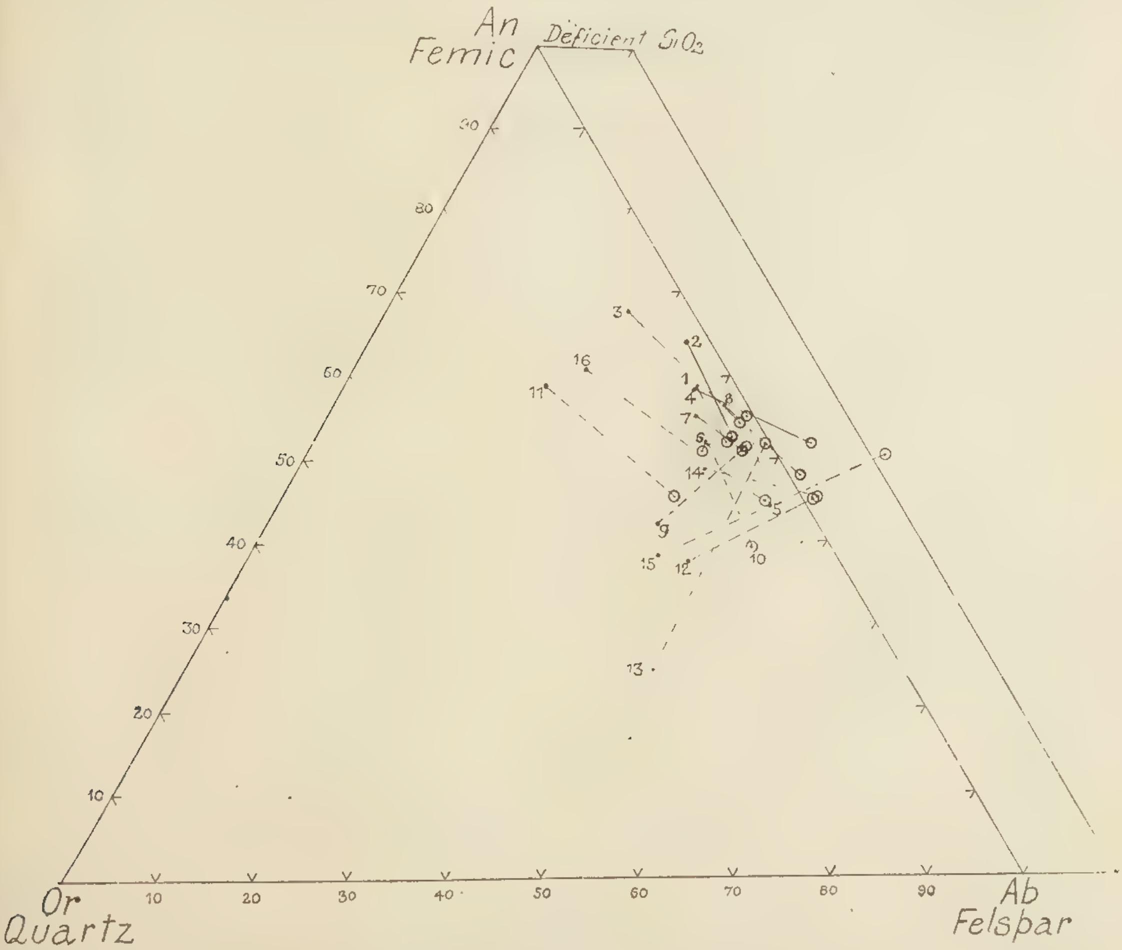
Text Fig. 7.—Diagram showing the MgO-CaO-FeO ratios of the normative pyroxene in the quartz dolerites and epidiorites of the Darling Range near Perth, and their relationship to the hornblende field (49). Insert is variation diagram of Na_2O plotted against distance from the hornblende field. 1, Epidiorite, Smith's Mill (83, p. 28); 2, Epidiorite (fine-grained), Bickley Brook (20, p. 173); 3, Epidiorite (coarse-grained), Bickley Brook (20, p. 173); 4, Uralitized quartz dolerite, Armadale (74, p. 45); 5, Quartz dolerite, Toodyay (76, p. 127).

contact metamorphosed. To my knowledge there are no post-epidiorite intrusions in this area and the presence of smoky felspars in these rocks does not appear to be explicable by contact metamorphism. Further work especially on the chemical composition of the pyroxenes and amphiboles and on the smoky felspars, is necessary before the origin of these epidiorites is completely known—they are however closely related to the quartz dolerites. The chemical characters of the quartz dolerites and related rocks are illustrated in Text Fig. 8.

C. IGNEOUS ROCKS OF UNKNOWN AGE.

In the southern half of the State dyke intrusions have been noted which do not appear to be related to the quartz dolerites just mentioned. All that can be said of their age is that they are post-gold or post-granite. They include:—

(i) *Norites.* These have been recorded from a number of widespread localities thus:—Norseman (7, p. 24) in the Dundas G.F., Barloweerie Peaks (11, p. 64) in the Murchison G.F., Ora Banda (47, p. 112) in the



Text Fig. 8.—**Late Nullagine Quartz Dolerites**—Larsen triangular diagrams (50) of rocks which appear to belong to the late-Nullagine hypabyssal activity. Circles are quartz-felspar-femic ratios, dots are or-ab-an ratios. The connecting lines are shown full for the rocks from the southern part of the State and broken for those from the northern parts of the State. Note that there appears to be more uniformity in the rocks of the southern part of the State than in the northern part. 1, Epidiorite (coarse centre of dyke), Bickley Brook (20, p. 173); 2, Quartz dolerite, Toodyay (76, p. 127); 3, Uralitized quartz dolerite, Armadale (74, p. 45); 4, Biotite epidiorite, Armadale (74, p. 49); 5, Epidiorite, Smith's Mill (83, p. 28); 6, Quartz dolerite, Morawa (84); 7, Gneissic epidiorite, Lower Palinup River (84); 8, Epidiorite, Mt. Singleton (84); 9, Dolerite, Mt. Holmes (83, p. 34); 10, Dolerite, Nullagine (83, p. 46); 11, Tachylite (selvage to dolerite dyke), Poona (83, p. 32); 12, Two-pyroxene quartz dolerite, Upper Prince Regent River (83, p. 22 and 25, p. 88); 13, Two-pyroxene dolerite, Synnott Creek (83, p. 22 and 25, p. 88); 14, Dolerite, Irregully Creek (83, p. 32); 15, Two-pyroxene dolerite, Mt. Lyell (83, p. 32 and 25, p. 88); 16, Two-pyroxene quartz dolerite, near F.B. 66, North Kimberley (25, p. 88).

Broad Arrow G.F., Fraser's Range (58, p. 8), and the Cavenagh and Blackstone Ranges (94, p. 132 and 178) in the Warburton Region. Simpson (101, p. 51) considers that a rock from Cue which had previously been regarded as a norite, is actually a gabbro.

The norites of the Warburton Region occur in three large patches in the granitic gneisses, the total area of norite probably exceeding 160 square miles (94, p. 96) and the main type appears to be olivine norite. Thomson, who was the first to describe these rocks, considered them to be related to the quartz dolerite magma and also to the norites of Norseman (96, p. 311) and in this is followed by later writers. The Warburton norites are intruded by basaltic dolerites (94, p. 97) [in the sketch plan given by Talbot and Clarke olivine norite is indicated as "gabbro"]. Talbot and Clarke (94, p. 96) note that some doubt is thrown on their observation of the relative ages of norite and basaltic dolerite, by petrological evidence, since the basaltic dolerites are more altered than the olivine norite. In my opinion the alteration of the basaltic dolerite is a deuteric effect and is in no way related to dynamothermal metamorphism and in the vicinity of Dangin (78) I have found a somewhat similar petrological example where perfectly fresh charnockitic rocks (hypersthenites etc.) are intruded by strongly uralitised basaltic dolerites. Petrological evidence is therefore not contrary to the field evidence that in the Warburton Region the dolerites are younger than the norites. In view of this pre-dolerite age of the olivine norites and of the occurrence of charnockitic rocks such as garnet-hypersthene gneisses in this Region it is probable that the Warburton norites are related to the charnockitic suite of pre-granite age (similar to the charnockitic xenoliths in the older granitic gneisses at Dangin (78)). It is, in my opinion, very doubtful whether the Warburton norites are genetically related to the late-Nullagine quartz dolerite magma as suggested by Thomson.

The most typical of the norite occurrences is that of Norseman which is considered by Campbell (7, p. 24) to be the most recent of the dyke intrusions in the Dundas G.F.—it varies from half a mile to one mile wide and traverses the Norseman area from east to west. Within this dyke all gradations between norite and hypersthenite are present and it is possible that this is due to gravitative differentiation and that the dyke is perhaps a rather flat-lying intrusion—this can only be determined by detailed petrological investigation of rocks from different parts of the dyke, an investigation that is at present under way. Further comparative petrological studies of the Warburton range and Norseman norites are also desirable. Maitland (59, p. 82) considers that these norites are probably of Tertiary age. This question is discussed further when dealing with the igneous activity of the Kainozoic. It appears to me that the norites are best regarded as Pre-Cambrian.

(ii) *Picrites.* An interesting occurrence of porphyritic olivine picrite has been noted by Farquharson from south of the Golden Mile at Kalgoorlie (28, p. 28). He considers that this occurrence is a picrite dyke rather than an olivine basalt flow and that it is younger than the albitic porphyry and therefore the youngest intrusive in the Kalgoorlie area (*loc. cit.* p. 33). The only other locality in Western Australia where this type of rock is known to occur is St. Ives (28, p. 31) where it occurs in a dyke intruding the greenstones (13, p. 13). In the St. Ives District

there are also dykes of the Norseman norite mentioned above and it is probable that there is some genetic relationship between the norites and picrites. As noted above the age of these dykes cannot be definitely fixed, but they are best regarded as Pre-Cambrian. It is probable that the Kalgoorlie and St. Ives picrites, the latter having been originally described by Farquharson (13, p. 13) as an olivine dolerite, belong to the earlier more basic olivine dolerite phase of the late-Nullagine quartz dolerite magma.

(iii) *Lamprophyres*: These have been noted at Cue, Paynesville, Leonora, Murrin Murrin, Mt. Morgans, Eulaminna, Wiluna and the Cavenagh Range. The petrography of this group has recently been dealt with by Miles (69) who finds that kersantites, augite minettes, hornblende and augite camptonites are represented in the known occurrences. No information is available regarding their age other than they are intrusive into the Archaeozoic metamorphic rocks.

(iv) *Serpentines*: Some occurrences of serpentinised ultra-basics may be later than the Younger Greenstone Series to which many of the ultrabasic rocks, as previously indicated, are undoubtedly related. Such a serpentine dyke has been described from Toodyay (76, p. 128).

(v) *Phonolite* (discredited) has been recorded from the South end of Parker's Range in the Yilgarn Goldfield (27, p. 85). As other nepheline-bearing rocks are unknown in Western Australia I re-examined this specimen, for the loan of which I am indebted to the Government Geologist, Mr. F. G. Forman. Re-examination shows that the mineral mistaken for nepheline is an untwinned oligoclase and that the rock is not a phonolite but a much altered porphyrite.

D. METAMORPHISM ASSOCIATED WITH PROTEROZOIC IGNEOUS ACTIVITY.

The rocks of the Nullagine System show very little sign of constructive metamorphism, the grade of metamorphism everywhere being very low. Perhaps the highest grade of regional metamorphism is to be found in the chlorite zone pelites of the Stirling Range and in the economically important crocidolite (blue asbestos)—bearing rocks of the Hamersley Ranges. Miles considers that the development of crocidolite in the banded ironstones of this region is due to recrystallization of material already present in the ironstones, under conditions of mild load metamorphism (66, p. 37) and that igneous intrusions have not been responsible for its formation (*loc. cit.* p. 35).

Contact metamorphism in the vicinity of the dolerite dyke intrusions has been noted in a few places only. At Armadale, biotite and chloritoid have been developed in the slates as a result of contact metamorphism by epidiorite and dolerite intrusions (74, p. 43). At Soanesville in the Pilbara, asbestos deposits occurring in serpentine at the margins of intrusive dolerite dykes are considered by Blatchford (1, p. 47) to be contact deposits due to the dolerite dykes. The Silversheen Asbestos deposits located 120 miles South-East from Onslow also, owe their origin to the contact effect of the intrusive dolerites which have caused the development of high grade chrysotile deposits in the dolomitic limestones of Nullagine age. Matheson (62) considers that the ochre deposits of the Ophthalmia Range are due to the contact alteration of hematite-bearing metasediments by intrusive quartz dolerite. This alteration, noticed only near the contact of the quartz dolerite and the metasediments, involves the change of specular hematite of the

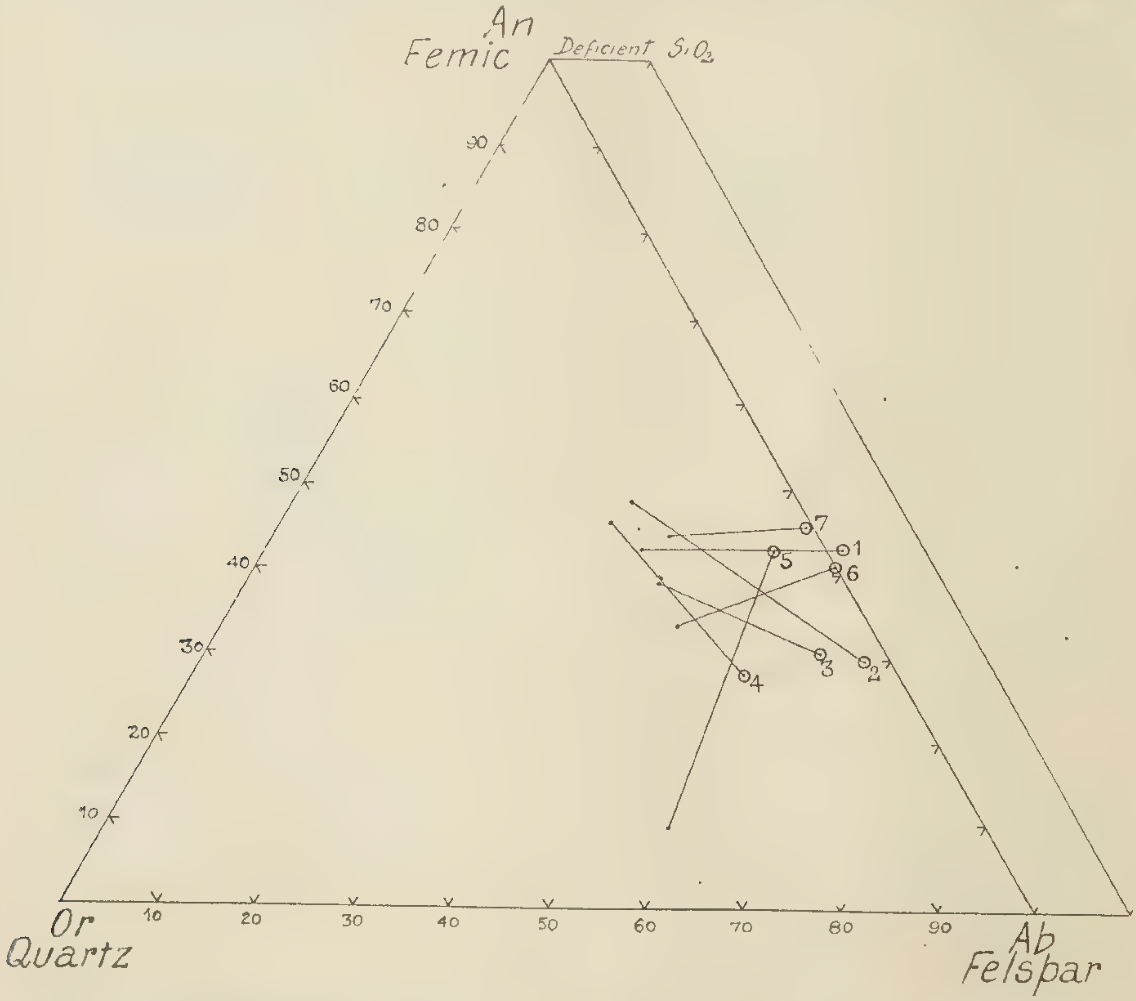
metasediments to ochreous hematite. It has not been effected by weathering, which has the effect of changing the hematite to limonite, the presence of which detracts from the quality of the ochre.

E. ORE-FORMATION ASSOCIATED WITH PROTEROZOIC IGNEOUS ACTIVITY.

In contrast to the auriferous metallization of the Archaeozoic, metallization of the Proterozoic formations was entirely of the base metal type. The most important examples of mineralization of the Nullagine rocks are the lead deposits of Braeside (34) and the copper deposits of Whim Creek (2 and personal communication from R. S. Matheson). Other lead and copper deposits of minor importance and similar nature occur at various localities in the Pilbara region and it is considered that all these deposits are genetically related to the Proterozoic basic magma (87, p. 218).

V.—CAMBRIAN VOLCANISM.

Igneous activity that can definitely be assigned to the Cambrian period is limited in its occurrence to the northernmost part of the State. Basaltic outflows of this period cover extensive tracts in the Antrim Natural Region



Text Fig. 9.—**Cambrian Basalts**—Larsen triangular diagrams (50). Circles are quartz-felspar-femic ratios, dots are or ab an ratios. 1, Olivine basalt, Fish Pool (26, p. 86); 2, Felspar basalt, Hearten's Homestead (26, p. 87); 3, Aphyric basalt, Negri River (26, p. 89); 4, Quartz basalt, near Hardman Range (26, p. 89); 5, Quartz basalt, "The Seven Mile" near Wyndham (26, p. 89); 6, Sub-ophitic basalt, Flora Valley Station (26, p. 89); 7, Aphanitic basalt, Martin's silver-lead mine (26, p. 89). Note that No. 5 does not appear to belong to the suite. Professor Clarke (who collected this specimen) informs me that he has always had some doubt as to whether or not this specimen was a Cambrian basalt.

of the North-East Kimberley and extend into the Northern Territory. They are reported to attain a thickness of as much as 3,000 feet in some localities. The occurrence and petrology of these basalts has recently been described by Edwards and Clarke (26) who have set down all the available field information and described all the specimens that have been collected from these flows. The basalt flows are practically horizontal and in places (in the Negri River area) are overlain by agglomerates and bedded tuffs which in turn are overlain by Cambrian limestones. Basalts of the Antrim Plateau are regarded by Clarke (26, p. 84) as lying above the Cambrian limestones rather than below them as in the Negri River, suggesting that there were two distinct periods of volcanicity. Petrologically they form a single series ranging from olivine basalts to quartz basalts and have distinct affinities with the tholeiitic magma type and in this they are similar to the quartz dolerite dykes discussed in connection with Nullagine activity. Edwards (25, p. 87) considers that although the Nullagine basalts of the North Kimberley resemble, in their chemical composition, those of the East Kimberley, "the varieties of basalt known to occur in the two regions cannot be matched." It seems probable however that the quartz dolerite dykes which intrude the Nullagine basalts represent a hypabyssal phase of the Cambrian volcanism —that they were the channels through which the extensive Cambrian flows were erupted. The available chemical analyses of the Cambrian basalts are shown graphically in Text Fig. 9.

The Cambrian period was then a period of igneous activity which began with the fissure eruptions of Lower Cambrian times. The hypabyssal phase of these extrusions is probably represented by the quartz dolerite dykes of the North Kimberley and of the southern part of the State from which all traces of the surface extrusions, if, indeed the magma ever reached the surface in these areas, have been removed by erosion. After the comparatively quiet fissure eruptions there appears to have been later explosive activity yielding the overlying agglomerates and tuffs (none of which appear to have been petrologically examined). In mid-Cambrian or even later times there may have been a further outburst of basaltic lava from the same magma as that yielding the Lower Cambrian flows.

This brings to a close the fairly continuous sequence of igneous activity which began in the early Archaeozoic. From Cambrian times onward, Western Australia was a very stable area and was not subjected to extensive earth movements or igneous activity except for small scale volcanism in Tertiary times.

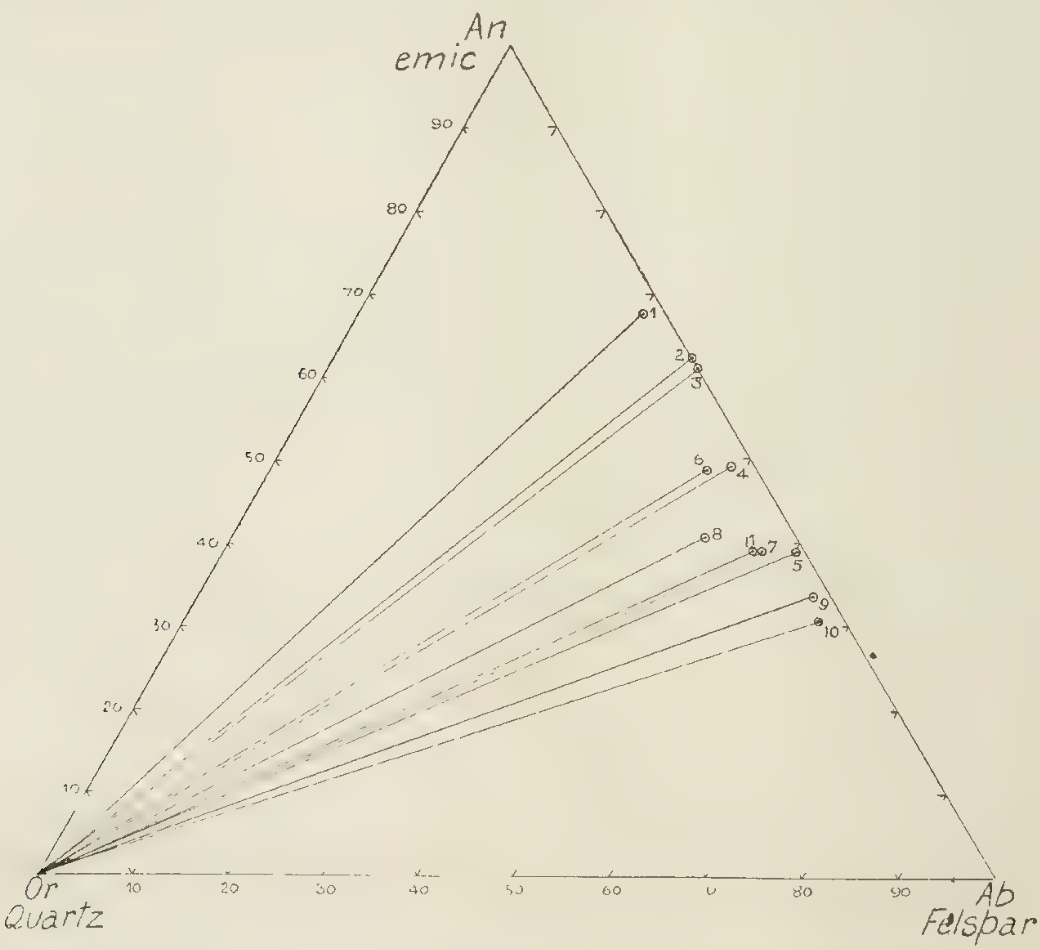
VI.—THE PERIOD FROM THE CAMBRIAN TO THE TERTIARY.

Throughout this period there is no evidence of any igneous activity in Western Australia. This is in marked contrast to the eastern part of Australia where there was extensive igneous activity throughout the Palaeozoic and on a somewhat decreased scale in the Mesozoic The economically important metallogenic epochs in eastern Australia with the exception of Broken Hill) are, as a consequence, much more recent than those of Western Australia. In eastern Australia the most important period of ore-formation was associated with the granite and granodiorite intrusions of Devonian times whereas in Western Australia, as we have seen, the late-Archaeozoic

was the main period of ore formation, and the late-Proterozoic the period when the less important non-auriferous base-metal deposits were formed.

VII.—KAINOZOIC VOLCANISM.

Two markedly different types of volcanism took place comparatively late in the geological history of Western Australia. These were the short-lived explosive lamproite eruptions of the Fitzroy Valley in the Kimberley and the comparatively quiet outpourings of basalt in the lower South-West. In neither case is it possible to assign these eruptions to a definite period. Mt. Yates in the East Kimberley approximately 60 miles due south from Wyndham is a volcanic plug intrusive into Nullagine (Proterozoic) quartzites (26, p. 85). In view of the preservation of this plug protruding through the Nullagine quartzites, Professor Clarke (personal communication) considers that it may probably be of Kainozoic age. Unfortunately however all the available specimens from this plug are too weathered to be of any use for determination of the type of rock (26, p. 85). Heavy mineral analyses of these rocks recently made in the Geology Department of the University of Western Australia showed no remnants of any original minerals.



Text Fig. 10.—**Kainozoic Leucite Lamproites**—Larsen triangular diagrams (50). Circles are quartz-felspar-femic ratios, and in all rocks of this suite the normative felspar is 100% orthoclase. 1, Carbonated wolgidite, Wolgidee Hills (99, p. 75); 2, Coarse fitzroyite, Mt. North (79); 3, Wolgidite, Mt. North (99, p. 75); 4, Cedricite, Mt. Gytha (99, p. 75); 5, Fitzroyite, Mamilu Hill (79); 6, Olivine leucite lamproite, Mt. North (79); 7, Mamilite, Mamilu Hill (79); 8, Fitzroyite, Dadja Hill (99, p. 75); 9, Cedricite, Mamilu Hill (79); 10, "Fine-grained wolgidite," "P" Hill (79 and 99, p. 75); 11, Mamilite, Hill's Cone (99, p. 75).

A. LAMPROITES OF THE FITZROY VALLEY.

In the Fitzroy valley in the West Kimberley nineteen small, much dissected volcanoes have been located. These volcanic occurrences are in the form of circular or oval plugs occupying gas-drilled pipes which have penetrated the Permian strata of the Desert Artesian Basin. The only direct evidence of age of this activity is that the plugs are intrusive into the Upper Ferruginous (Liverynga) Series of the Upper Permian, but other evidence such as the preservation of the structure of the plugs makes it likely that they are no older than the Kainozoic. The volcanic rocks of these plugs belong to the rare group of lamproites and comparable rock types have been located only at the Leucite Hills, Wyoming, U.S.A. The occurrences and petrology have been described by Dr. Wade and myself (99) and I have recorded further details regarding the petrological structure of the vents in an unpublished Mss. (79).

The rocks consist of various associations of altered leucite with diopside, titaniferous phlogopite and potash-magnesia amphibole, and have yielded two new minerals, magnophorite (the potash-magnesia amphibole) and wadeite (a potassium-zirconium silicate) (71). Both massive lamproite and lamproite breccias are developed but the breccias are considered to be of non-extrusive origin rather than sub-aerial pyroclastics. All of the rocks examined are undoubtedly co-magmatic and the magma from which they were developed was of peculiar character and is considered to be genetically related to a mica-peridotite parent, the lamproite plugs representing the uppermost parts of kimberlite plugs. The available chemical analyses of these rocks are graphically illustrated in Text fig. 10 in which however the minor substances cannot be shown—these minor constituents such as BaO, SrO, ZrO_2, TiO_2, P_2O_5 and F are comparatively abundant in these lamproites.

The volcanism giving rise to these lamproites was probably of very limited duration, at least as far as its surface manifestation was concerned and has produced very little effect on the intruded country rocks. These volcanic plugs have, however, been more resistant to erosion than the Permian sediments and at the present form the most marked features of the topography of this region.

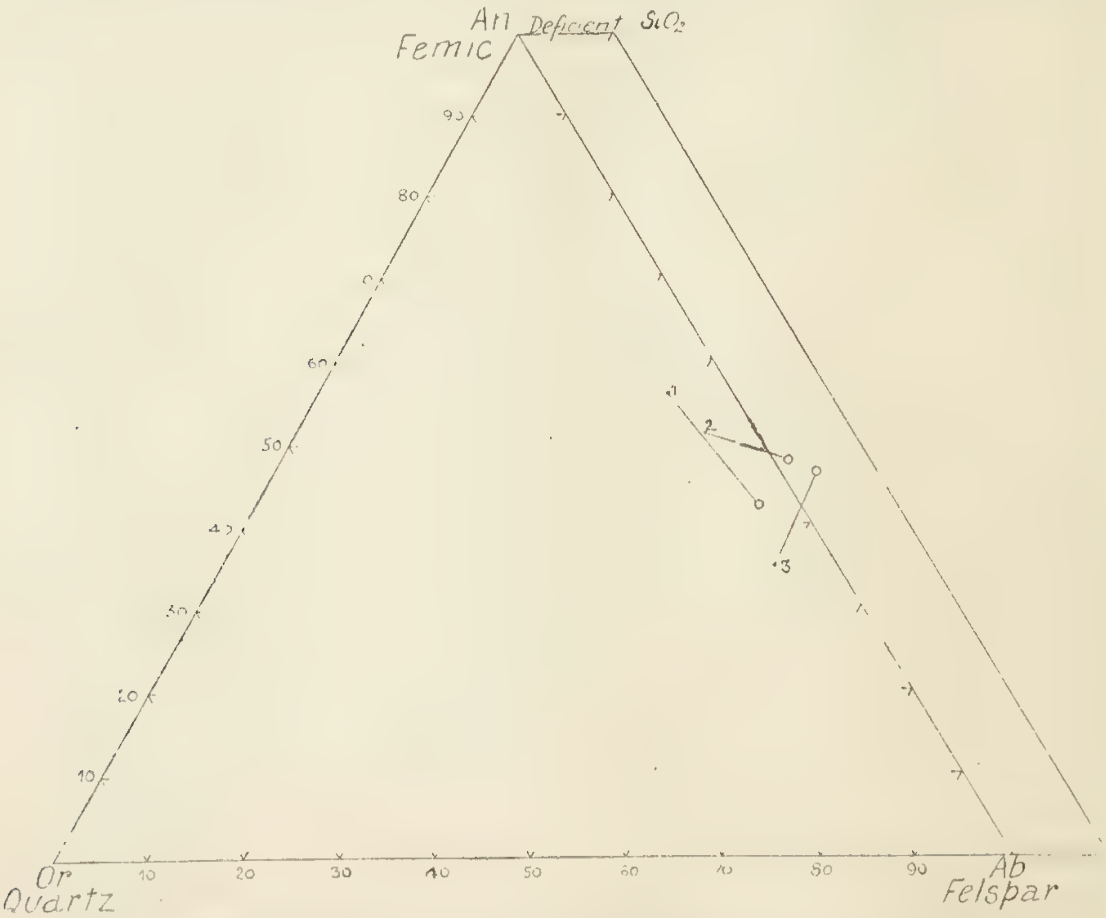
The activity of the lamproite magma was probably accompanied by small-scale ore-formation. At Narlarla in the vicinity of the Barker Gorge, several small silver-lead-zinc ore-bodies occur in the Devonian limestones—these, although not of commercial importance, are unique as they are the only post pre-Cambrian primary ore-bodies in the whole of Western Australia. These I consider are genetically related to the post-Permian lamproite magma (75, p. 64). Some of these lamproites, especially the coarse grained wolgidites are very similar to the diamond-bearing rock kimberlite and it is quite possible that diamonds may occur in these lamproites, especially in the large volcanic pipes such as the Wolgidee Hills vent which is approximately 1½ miles in diameter. Another economically important aspect of this volcanism is in connection with the prospects for petroleum in this area, which, up-to-date is regarded as the most promising area in Western Australia. Wade (98, p. 29) concludes that the presence of these volcanic vents would not affect adversely the chances of finding oil in this region,

B. THOLEIITES OF THE SOUTH-WEST.

These basaltic rocks are probably the youngest igneous rocks of Western Australia being considered to be of Sub-Recent age (19, p. 27). They occur

at various localities (24, p. 10) in the narrow trough-like area of younger rocks flanked at the east and west by Archaeozoic rocks, which extends from Geographe Bay to the south coast at Flinders Bay. The occurrence and petrology of these basalts has been dealt with by Edwards (23, 24) who finds that they are of tholeiitic character, of constant chemical and mineralogical composition but ranging from mega—to micro—porphyritic types. The available chemical analyses are illustrated in Text fig. 11. Insufficient evidence is available to indicate whether this period of igneous activity is represented by a single flow or by a series of separate flows, but borings at Bunbury (24, p. 11) indicate the presence of one flow only. Whether the flows noted in various places in the lower South West are fissure eruptions or flows from isolated vents is also unknown, but a study of the well marked curved joint systems in the Cape Gosselin outcrops (Text fig. 12) may yield information in this connection.

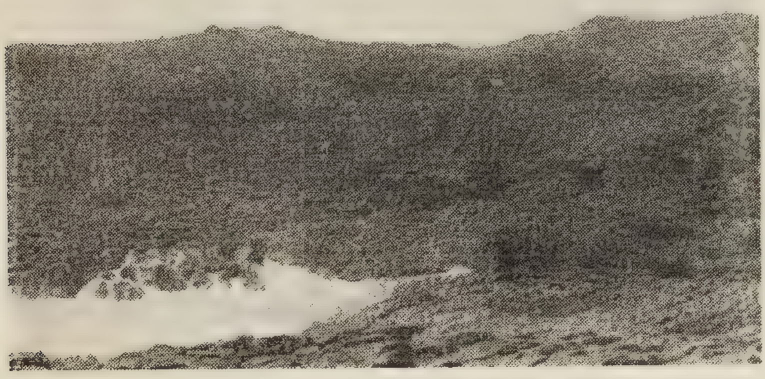
Edwards suggests (24, p. 8), following Gibb Maitland (57, p. 42) that the tholeiite magma was not confined to the south-west corner of the State but was more widespread, and he cites a number of localities where rocks which may be related to the Tertiary tholeiitic magma occur. On the occurrences listed (other than those of the norites, the age of which is unknown) the most likely, from their relations to the country rocks, to belong to this



Text Fig. 11.—**Tertiary Tholeiites**—Larsen triangular diagrams (50). Circles are quartz-felspar-femic ratios, dots are or-ab-an ratios. 1, Donnelly River (24, p. 6); 2, Bunbury (24, p. 6); 3, Cape Gosselin (23, p. 21).

Tertiary activity are the basaltic dolerites of the Meekatharra area. These basaltic dolerites, which are also represented in other goldfields areas, are the youngest igneous rocks in the Meekatharra area, being intrusive into the greenstones and auriferous ore bodies (11, p. 64). To the north of

Meekatharra the dolerites are reputed to intrude the Oakover limestones which were formerly considered to be possibly of Tertiary age (11, p. 61)



Text Fig. 12.—Curved columnar jointing in the Tertiary tholeiite flow at Cape Gosselin.
Photo—E. de C. Clarke

but which Finucane now regards as Permo-Carboniferous (34, p. 4). As there is a very great doubt regarding the age of the Oakover limestones (which may even be the dolomitic phase of the Upper Nullagine) the evidence is not sufficiently strong, in my opinion, to differentiate the basaltic dolerites of the Oakover occurrences from the quartz dolerite (tholeiite) dykes of late-Proterozoic or even Cambrian age.

Jutson and Simpson (48, p. 48) mention that "at the brick pit about three miles to the north-west of Albany, a decomposed basic dyke cuts through not only the granite, but also the overlying marine sediments (the Plantagenet beds of Miocene age) . . . and may possibly be related to the basalts of which those at Bunbury are the type." This "decomposed basic dyke" has never been closely examined and no material from it is preserved in the collection of the Western Australian Geological Survey. I am indebted to Mr. R. A. Fowler of Albany for several specimens of weathered rock which appeared to him to be the dyke rock described by Simpson and Jutson. Heavy mineral separations of this material (one specimen was white, the other reddish) showed that the heavy minerals were identical in both samples. The minerals noted in the heavy fractions were tourmaline, zircon, rutile, kyanite and magnetite, none of which show any signs of rounding. The same set of minerals with similar habit and shape was obtained by heavy mineral separations of a sample of "sediment of the Plantagenet Series" collected several years ago by Dr. Teichert, so there can be little doubt that the material collected for me by Mr. Fowler is from the Plantagenet beds. It is possible however that this material is not that described by Simpson and Jutson and further investigation is desirable to verify Jutson and Simpson's diagnosis since, other than the basalts outcropping between Bunbury and Cape Gosselin it is, if of igneous origin, the only example of undoubted Tertiary igneous activity in the southern half of the State. It may be noted here that the norite of Norseman, considered by Gibb Maitland (59, p. 82) and Edwards (24, p. 8) to belong to the Tertiary tholeiitic magma, is, according to Campbell (7, fig. 4 on p. 22) older than the Miocene fossil bed and therefore much older than the Albany "dyke" and the Bunbury basalt. It is most probable I think that

the basaltic dolerites of the Goldfields areas, rather than being of Tertiary age, are contemporaneous with the late-Proterozoic or Cambrian quartz dolerites and that the Tertiary tholeiites are confined to the trough extending from Bunbury to Cape Gosselin—otherwise we should expect somewhere amongst the Permian, Jurassic and Cretaceous rocks to find some traces of basic dykes. Such intrusives have never been recorded.

The occurrence of authentic Tertiary tholeiites appears to be confined to the trough of younger rocks between Bunbury and the South coast and this would indicate some tectonic significance for these outflows (60, p. 188), viz., that this trough, to which they are confined, is a rift valley.

VIII.—CONCLUSION.

This brings us to the end of our excursion through geological time in which we have glanced briefly at the evidences of igneous activity and related phenomena to be seen in Western Australia. There is no sign of present day igneous activity except possibly the hot springs of the Fitzroy Valley in the West Kimberley (3, pp. 11 & 29). These springs may be derived from deep artesian horizons, but I have noticed that water from comparatively shallow depths of one or two hundred feet is noticeably warm, indicating an abnormally high thermal gradient in this area. Is this due to some superficial phenomenon? Or is it evidence of igneous activity, either the waning activity of the lamproite magma, or evidence of an approaching period of volcanism in this area?

The subject of my address has, I feel, been an academic one, lacking the economically important nature of recent Presidential addresses to this Society, but in our geological studies we should not be hampered by being confined to economically important matters, but our efforts should be directed rather towards a better understanding of natural processes and the nature of the earth on which we live. If the publication of the matter which I have placed before you this evening provokes discussion, we cannot, I feel, do other than come to a better understanding of geological phenomena in Western Australia and in so doing equipping ourselves the better to undertake a very important responsibility in this world of quickly diminishing mineral reserves—the exploitation of our natural mineral resources.

IX.—ACKNOWLEDGMENTS.

It is a pleasure to record here my thanks to my colleagues, Professor E. de C. Clarke and Dr. Teichert of the Department of Geology of the University of Western Australia, and my friends Messrs. Forman, Ellis, Hobson and Matheson of the Geological Survey of Western Australia, for many helpful discussions concerning the igneous record in Western Australia. Professor Clarke has rendered me invaluable assistance in criticising the text of this paper and for such criticism I am very grateful. It gives me especial pleasure to record my indebtedness to Professor Clarke, to whom I owe my introduction to geology and who has always given freely of his advice and assistance in any research that I have attempted. I am indebted also to the Government Geologist (Mr. F. G. Forman) and the Government Mineralogist and Analyst (Mr. H. Bowley) for permission to quote from unpublished reports from their respective Departments.

X.—LIST OF WORKS TO WHICH REFERENCE IS MADE.

1. Blatchford, T., 1913: Mineral Resources of the North-West Division, *Geol. Surv. West. Aust. Bull.* 52.
2. Blatchford, T., 1921: Report on the Whim Well and Mons Cupri Mines, *West. Aust. Dept. of Mines Rept.*
3. Blatchford, T., 1927: The Geology of Portions of the Kimberley Division, with Special Reference to the Fitzroy Basin and the Possibilities of the Occurrence of Mineral Oil, *Geol. Surv. West. Aust. Bull.* 93.
4. Blatchford, T., and Honman, C. S., 1917: The Geology and Mineral Resources of the Yilgarn Goldfield, Part III, *Geol. Surv. West. Aust. Bull.* 71.
5. Blazey, E. L., *et al.*, 1938: Geophysical Report on the Wiluna Area, *Aer. Geol. Geophys. Surv. North. Aust., West. Aust. Rept. No.* 36.
6. Campbell, W. D., 1904: Canning River Reservoir, and Helena River Valley. Geological maps in *Geol. Surv. West. Aust. Ann. Rept. for* 1903.
7. Campbell, W. D., 1906: The Geology and Mineral Resources of the Norseman District, *Geol. Surv. West. Aust. Bull.* 21.
8. Canavan, F., and Edwards, A. B., 1938: The Iron Ores of Yampi Sound, Western Australia, *Proc. Aust. Inst. Min. Met.* new ser. No. 110, pp. 59-101.
9. Carroll, D., 1937: Some Aspects of Soil Mineralogy, *Journ. Roy. Soc. West. Aust.*, XXIII., pp. 7-11.
10. Carroll, D., 1940: Granitization at Cape Leeuwin,'' *Aust. Journ. Sci.*, II., pp. 167-170.
11. Clarke, E. de C., 1916: The Geology and Ore Deposits of Meekatharra, *Geol. Surv. West. Aust. Bull.* 68.
12. Clarke, E. de C., 1923: The Pre-Cambrian System in Western Australia. *Journ. Roy. Soc. West. Aust.*, IX., pt. II, pp. 13-37.
13. Clarke, E. de C., 1925: The Geology of . . . . Monger and St. Ives, *Geol. Surv. West. Aust. Bull.* 90.
14. Clarke, E. de C., 1927: Natural Regions in Western Australia, *Journ. Roy. Soc. West. Aust.*, XII., pp. 117-132.
15. Clarke, E. de C., 1931: The Pre-Cambrian Succession in Some Parts of Western Australia, *Rept. Aust. N.Z. Ass. Adv. Sci.*, XX., pp. 155-192.
16. Clarke, E. de C., 1936: Water Supply in the Kalgoorlie and Wheat Belt Regions of Western Australia, *Journ. Roy. Soc. West. Aust.*, XXII., pp. xi-xliii.
17. Clarke, E. de C., 1938: Middle and West Australia, Bd. 1, Abs. VII. of *Reg. Geol. der Erde, Akad. Verlag.* (Leipzig).
18. Clarke, E. de C., and Ellis, H. A., 1939: Metasomatism of Country Near-Ore Bodies and its Possible Economic Significance, *Econ. Geol.*, XXXIV., pp. 777-789.
19. Clarke, E. de C., Prider, R. T., and Teichert, C., 1944: Elements of Geology for Western Australian Students (*Univ. West. Aust. Text Books Board*, Crawley).
20. Clarke, E. de C., and Williams, F. A., 1926: The Geology and Physiography of Parts of the Darling Range near Perth, *Journ. Roy. Soc. West. Aust.*, XII., pp. 161-178.
21. Cole, W. F. and Gloe, C. S., 1940: ''The Geology and Physiography of the Malkup Area,'' *Journ. Roy. Soc. West. Aust.*, XXVI., pp. 139-171.
22. Davis, C. E. S., 1942: ''The Geology and Physiography of the Gosnells Area,'' *Journ. Roy. Soc. West. Aust.*, XXVII., pp. 245-264.
23. Edwards, A. B., 1936: ''Tholeiite basalts from Cape Gosselin, Western Australia,'' *Journ. Roy. Soc. West. Aust.*, XXII., pp. 19-23.
24. Edwards, A. B., 1938: ''Tertiary tholeiite magma in Western Australia,' *Journ. Roy. Soc. West. Aust.*, XXIV., pp. 1-12.
25. Edwards, A. B., 1942: ''Some basalts from the North Kimberley, Western Australia,'' *Journ. Roy. Soc. West. Aust.*, XXVII., pp. 79-93.
26. Edwards, A. B., and Clarke, E. de. C., 1941: ''Some Cambrian basalts from the East Kimberley, Western Australia,'' *Journ. Roy. Soc. West. Aust.*, XXVI., pp. 77-94.
27. Ellis, H. A., 1939: ''The Geology of the Yilgarn Goldfield, south of the Great Eastern Railway,'' *Geol. Surv. West. Aust. Bull.* 97.

54. Maitland, A. Gibb, 1903: "Notes on the country between Edjudina and Yundamindera," *Geol. Surv. West. Aust. Bull.* 11.
55. Maitland, A. Gibb, 1908: "The Geological Features and Mineral Resources of the Pilbara Goldfield," *Geol. Surv. West. Aust. Bull.* 40.
56. Maitland, A. Gibb, 1919: "The Gold Deposits of Western Australia," *Geol. Surv. West. Aust. Mem.* No. 1.
57. Maitland, A. Gibb, 1924: "The Geology and Mineral Industry of Western Australia," *Geol. Surv. West. Aust. Bull.* 89.
58. Maitland, A. Gibb, 1925: "Notes on the country in the vicinity and to the northward of Israelite Bay," *Geol. Surv. West. Aust. Ann. Rept. for* 1924, pp. 4-9.
59. Maitland, A. Gibb, 1927: "The Volcanic History of Western Australia," *Journ. Roy. Soc. West. Aust.*, XIII., pp. 79-86.
60. Maitland, A. Gibb, 1939: "The Donnybrook Sandstone Formation and its Associates," *Journ. Roy. Soc. West. Aust.*, XXV., pp. 177-195.
61. Matheson, R. S., 1940: "Reports on some Mining Groups in the Yilgarn Goldfield," *Geol. Surv. West. Aust. Ann. Rept. for* 1939, pp. 18-43.
62. Matheson, R. S., 1945: "Report on Red Ochre Deposits, M.L. 370H, Ophthalmia Range," *Geol. Surv. West. Aust. Ann. Rept. for* 1944, pp. 35-37.
63. Miles, K. R., 1938: "The Geology and Physiography of the Lower Chittering Area," *Journ. Roy. Soc. West. Aust.*, XXIV, pp. 13-41.
64. Miles, K. R., 1941: "Some Kyanite-bearing rocks from the Eastern Goldfields, Western Australia," *Journ. Roy Soc. West. Aust.*, XXVII., pp. 9-25.
65. Miles, K. R., 1941: "Summary of petrological notes on some rocks from the Yilgarn Goldfield," *Geol. Surv. West. Aust. Ann. Rept. for* 1940, p. 18.
66. Miles, K. R., 1942: "The Blue Asbestos bearing banded iron formations of the Hammersley Ranges, Western Australia," *Geol. Surv. West. Aust. Bull.* 100, Part 1.
67. Miles, K. R., 1942: "Metasomatism near the Corinthian ore-body, Western Australia," *Proc. Aust. Inst. Min. Met.*, new ser. No. 125, pp. 71-83.
68. Miles, K. R., 1943: "Grunerite in Western Australia," *Amer. Min.*, 28, pp. 25-38.
69. Miles, K. R., 1948: "Some Western Australian lamprophyres," *Journ. Roy. Soc. West. Aust.*, XXXI pp. 1-16.
70. Phillips, F. C., 1930: "Some mineralogical and chemical changes induced by progressive metamorphism in the Green Bed group of the Scottish Dalradian," *Min. Mag.*, XXII., pp. 239-256.
71. Prider, R. T., 1939: "Some minerals from the leucite-rich rocks of the West Kimberley area, Western Australia," *Min. Mag.*, XXV., pp. 373-387.
72. Prider, R. T., 1940: "A note on the age relations of the basic porphyrites and albite porphyries of the Golden Mile, Kalgoorlie, Western Australia," *Journ. Roy. Soc. West. Aust.*, XXVI., pp. 99-101.
73. Prider, R. T., 1940: "Cordierite-anthophyllite rocks associated with spinel-hypersthenites from Toodyay, Western Australia," *Geol. Mag.*, LXXVII., pp. 364-382.
74. Prider, R. T., 1941: "The contact between the granitic rocks and the Cardup Series at Armadale," *Journ. Roy. Soc. West. Aust.*, XXVII, pp. 27-55.
75. Prider, R. T., 1941: "Hydrozincite from Narlarla, West Kimberley district, Western Australia," *Min. Mag.*, XXVI., pp. 60-65.
76. Prider, R. T., 1944: "The petrology of part of the Toodyay District," *Journ. Roy. Soc. West. Aust.*, XXVIII., pp. 83-137.
77. Prider, R. T., 1945: "Granitic rocks from Canning Dam," *Journ. Roy. Soc. West. Aust.*, XXIX., pp. 137-149.
78. Prider, R. T., 1945: "Charnockitic and related cordierite-bearing rocks from Dangin, Western Australia," *Geol. Mag.*, LXXXII., pp. 145-172.
79. Prider, R. T., —: "The leucite lamproites of the West Kimberley, Western Australia" (unpublished MSS).
80. Read, H. H., 1944: "Meditations on Granite, Part II.," *Proc. Geol. Assoc.*, LV., pp. 45-93.

28. Farquharson, R. A., 1923: "Some additions to the knowledge of the geology of Kalgoorlie, with special reference to the occurrence of a porphyritic olivine picrite," *Journ. Roy. Soc. West. Aust.*, IX., Pt. 1, pp. 23-33.

29. Feldtmann, F. R., 1916, "The Geology and Ore Deposits of Kalgoorlie," *Geol. Surv. West. Aust. Bull.* 69.

30. Feldtmann, F. R., 1919: "The magnesite deposits of Bulong," *Geol. Surv. West. Aust. Bull.* 82.

31. Feldtmann, F. R., 1921: "Preliminary report on the lead lodes of the Northampton Mining District," *Geol. Surv. West. Aust. Ann. Rept. for* 1920, pp. 15-18.

32. Feldtmann, F. R., 1936: "Contributions to the study of the Geology and Ore Deposits of Kalgoorlie, Part IV.," *Geol. Surv. West. Aust.* (unpublished report).

33. Finucane, K. J., 1936: "Bamboo Creek Mining Centre, Pilbara G.F.," *Aer. Geol. Geophys. Surv. North. Aust., West. Aust. Rept.* No. 9.

34. Finucane, K. J., 1938: "The Braeside Lead Field," *Aer. Geol. Geophys. Surv. North. Aust., West. Aust. Rept.* No. 14.

35. Fletcher, R. W., 1933: "Summary of the petrological report on the rocks from the Warburton Range Area," *Geol. Surv. West. Aust. Ann. Rept. for* 1932, p.8.

36. Fletcher, R. W., —: "Basic dykes of the South-West Division, Western Australia" (unpublished MSS.).

37. Fletcher, R.W., and Hobson, R. A., 1932: "The Physiography and Geology of the Upper Swan Area," *Journ. Roy. Soc. West. Aust.*, XVIII., pp. 23-37.

38. Forman, F. G., 1933: "Conclusions on Report of a Reconnaissance survey of the country between Laverton and the Warburton Range," *Geol. Surv. West. Aust. Ann. Rept. for* 1932, p. 6.

39. Forman, F. G., 1937: "A contribution to our knowledge of the Pre-Cambrian Succession in some parts of Western Australia," *Journ. Roy. Soc. West. Aust.*, XXIII., pp. xvii-xxvii.

40. Geological Survey of Western Australia, 1933: Geological Sketch map of Western Australia.

41. Gustafson, J. K. and Miller, F. S., 1937: "Kalgoorlie geology re-interpreted," *Econ. Geol.*, XXXII., pp. 285-317.

42. Hobson, R. A., 1940: "Progress Report on the geology of portion of the Mt. Margaret Goldfield," *Geol. Surv. West. Aust. Ann. Rept. for* 1939, pp. 15-18.

43. Hobson, R. A., 1941: "The Geology and Mining Groups of portion of the Mt. Margaret Goldfield," *Geol. Surv. West. Aust. Ann. Rept. for* 1940, pp. 10-11.

44. Holland, T. H., 1900: "The Charnockite Series . . . in Peninsular India," *Geol. Surv. India Mem.* XXXVIII.

45. Honman, C. S., 1914: "The Geology of the country between Kalgoorlie and Coolgardie," *Geol. Surv. West. Aust. Bull.* 56.

46. Honman, C. S., 1917: "The Geology of the North Coolgardie G.F. Part 1—the Yerilla District," *Geol. Surv. West. Aust. Bull.* 73.

47. Jutson, J. T., 1914: "The Mining Geology of Ora Banda," *Geol. Surv. West. Aust. Bull.* 54.

48. Jutson, J. T. and Simpson, E. S., 1916: "Notes on the Geology and Physiography of Albany," *Journ. Roy. Soc. West. Aust.*, II., pp. 45-58.

49. Kennedy, W. Q., 1936: "The influence of chemical factors on the crystallization of hornblende in igneous rocks," *Min. Mag.*, XXIV., pp. 203-207.

50. Larsen, E. S., 1938: "Some new variation diagrams for groups of igneous rocks," *Journ. Geol.*, 46, pp. 505-520.

51. MacGregor, A. G., 1931: "Clouded felspars and thermal metamorphism," *Min. Mag.*, XXII., pp. 524-538.

52. Maitland, A. Gibb, 1902: *Geol. Surv. West. Aust. Ann. Rept. for* 1901.

53. Maitland, A. Gibb, 1903: "The Geological Features and Mineral Resources of Northampton," *Geol. Surv. West. Aust. Bull.* 9.

81. Simpson, E. S. 1910: "Report on excursion to Mahogany Creek," *Journ. Nat. Hist. and Sci. Soc. West. Aust.*, III., p. 88.
82. Simpson, E. S., 1912: "The rare metals and their distribution in Western Australia," *Journ. Nat. Hist. and Sci. Soc. West. Aust.*, IV., pp. 83-108.
83. Simpson, E. S., 1916: "Analyses of Western Australian Rocks, Meteorites and Natural Waters," *Geol. Surv. West. Aust. Bull.* 67.
84. —— ——, —: Analyses of Western Australian rocks made subsequently to the publication of *Geol. Surv. West. Aust. Bull.* 67. From the files of the Government Chemical Laboratory and Geological Survey of Western Australia (unpublished).
85. Simpson, E. S., 1937: "Contributions to the Mineralogy of Western Australia, Ser. X.," *Journ. Roy. Soc. West. Aust.*, XXIII., pp. 17-35.
86. Simpson, E. S., 1938: "Contributions to the Mineralogy of Western Australia, Ser. XI.," *Journ. Roy. Soc. West. Aust.*, XXIV., pp. 107-122.
87. Simpson, E. S., 1939: "Mineral Provinces and Metallogenetic Epochs in Western Australia," *Journ. Roy. Soc. West. Aust.*, XXV., pp. 207-237.
88. Simpson, E. S., —: "The Minerals of Western Australia" (unpublished MSS).
89. Simpson, E. S., and Gibson, C. G., 1912: "The Geology and Ore Deposits of Kalgoorlie, Part 1," *Geol. Surv. West. Aust. Bull.* 42.
90. Stillwell, F. L., 1918: "The metamorphic rocks of Adelie Land, Section 1," *Aust. Ant. Exp.*, 1911-1914., III., pt. 1.
91. Stillwell, F. L., 1929, "Geology and Ore Deposits of the Boulder Belt, Kalgoorlie," *Geol. Surv. West. Aust. Bull.* 94.
92. Talbot, H. W. B., 1934: "The country north and west from Kalgoorlie," Western Mining Corporation Private report No. 72T/1. Unpublished.
93. Talbot, H. W. B., 1935: "Notes on the country east and north-east of Kalgoorlie," Western Mining Corporation Private Report No. 103T/1. Unpublished.
94. Talbot, H. W. B. and Clarke, E. de C., 1917: "A geological reconnaissance of the country lying between Laverton and the South Australian Border," *Geol. Surv. West. Aust. Bull.* 75.
95. Thomson, B. P., 1942: "The Geology and Physiography of the Wongong-Cardup Area," *Journ. Roy. Soc. West. Aust.*, XXVII., pp. 265-283.
96. Thomson, J. A., 1911: "On rock specimens from Central and Western Australia," *Journ. Proc. Roy. Soc. N.S.W.*, XLV., pp. 292-317.
97. Thomson, J. A., 1913: "The Petrology of the Kalgoorlie Goldfield," *Quart. Journ. Geol. Soc.*, LXIX., pp. 621-677.
98. Wade, A., 1936: "The Geology of the West Kimberley District of Western Australia." Final Report on concessions held by Freney Kimberley Oil Co. (1932), N.L.
99. Wade, A., and Prider, R. T., 1940: "The leucite-bearing rocks of the West Kimberley Area, Western Australia," *Quart. Journ. Geol. Soc.*, XCVI., pp. 39-98.
100. Wiseman, J. D. H., 1934: "The Central and South-West Highlands epidiorites: A study in progressive metamorphism," *Quart. Journ. Geol. Soc.*, XC., pp. 354-417.
101. Woodward, H. P., 1907: "The Cue and Day Dawn Districts," *Geol. Surv. West. Aust. Bull.* 29.
102. Woolnough, W. G., 1920: "A Geological Reconnaissance of the Stirling Ranges of Western Australia," *Journ. Proc. Roy. Soc. N.S.W.*, LIV., pp. 79-112.

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GENERAL INDEX.

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